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(12) **United States Patent**
Smith

(10) **Patent No.: US 9,069,152 B2**
(45) **Date of Patent: Jun. 30, 2015**

(54) **FURCATING FIBER OPTIC CABLES WITHOUT DIRECT COUPLING OF OPTICAL FIBERS TO STRENGTH MEMBERS, AND RELATED ASSEMBLIES AND METHODS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 204 days.

(21) Appl. No.: **13/792,870**

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Related U.S. Application Data

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(51) **Int. Cl.**
G02B 6/44 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/4476*** (2013.01); ***G02B 6/4479*** (2013.01); *G02B 6/4477* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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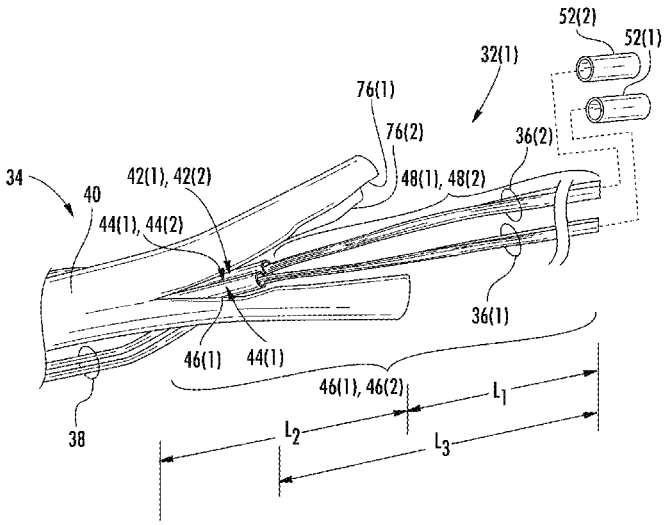
Primary Examiner — Mike Stahl

(57) **ABSTRACT**

Furcating fiber optic cables without direct coupling of optical fibers to strength members are disclosed. Related methods and assemblies are also disclosed. The furcation includes shrink tube(s) securing optical fiber(s) to their fiber sub-unit jacket(s). The shrink tube(s) is secured inside a cable jacket of the fiber optic cable to secure fiber sub-unit(s) and their optical fiber(s) as part of the furcation. The strength member(s) of the fiber optic cable is also secured to the cable jacket as part of the furcation. The shrink tube(s) prevents direct coupling of the optical fiber(s) to the strength member(s) in the furcation. By not directly coupling the optical fiber(s) to the strength member(s), cable strain can be directed to the cable jacket and the fiber sub-unit jacket(s). The shrink tube(s) can also prevent or reduce micro-bubbles from forming around the optical fiber(s) in the furcation which may cause attenuation from optical fiber micro-bending.

27 Claims, 17 Drawing Sheets



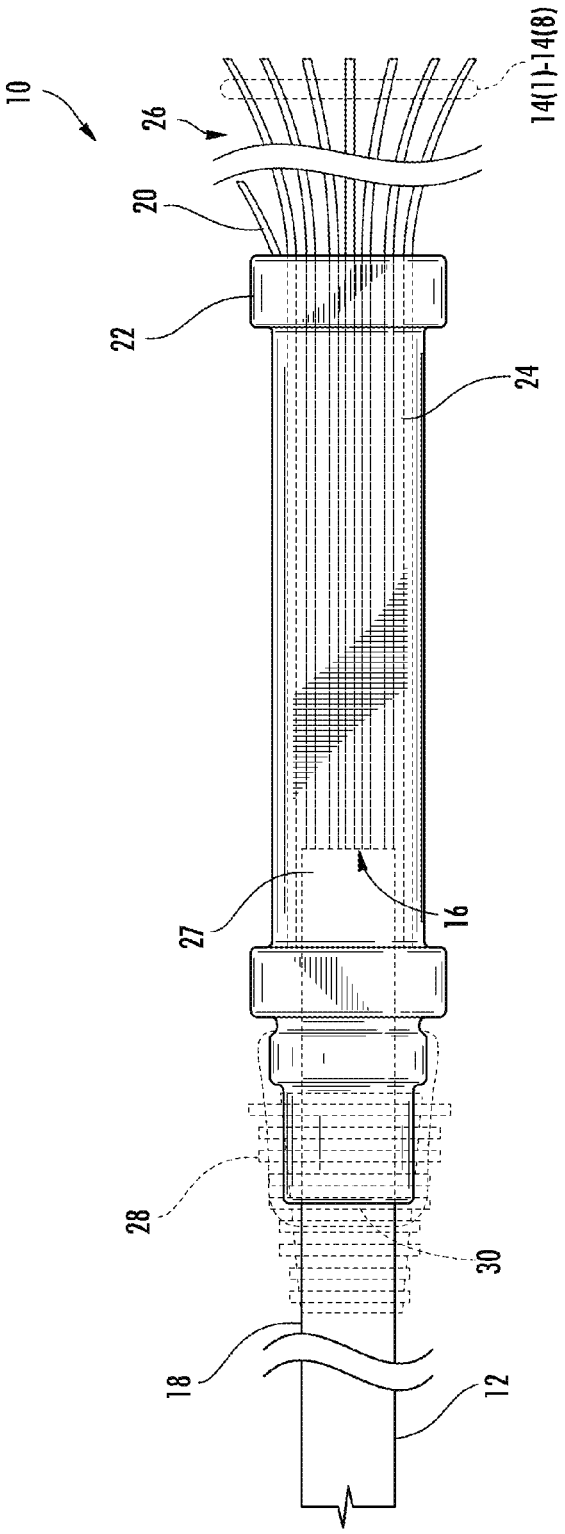
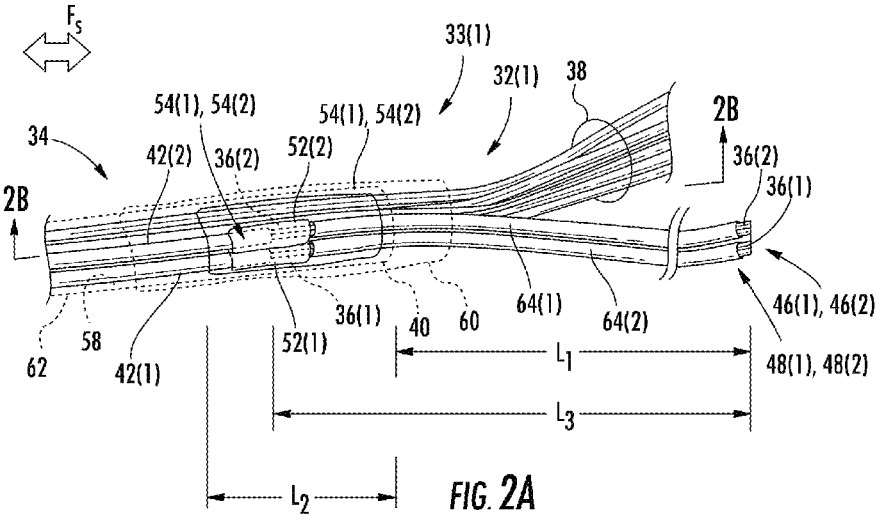


FIG. 1
PRIOR ART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2B
2B
36(2)
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36(1)
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60
64(1)
64(2)
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62
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42(1)
52(1)
L1
48(1), 48(2)
L3
L2

FIG. 2A

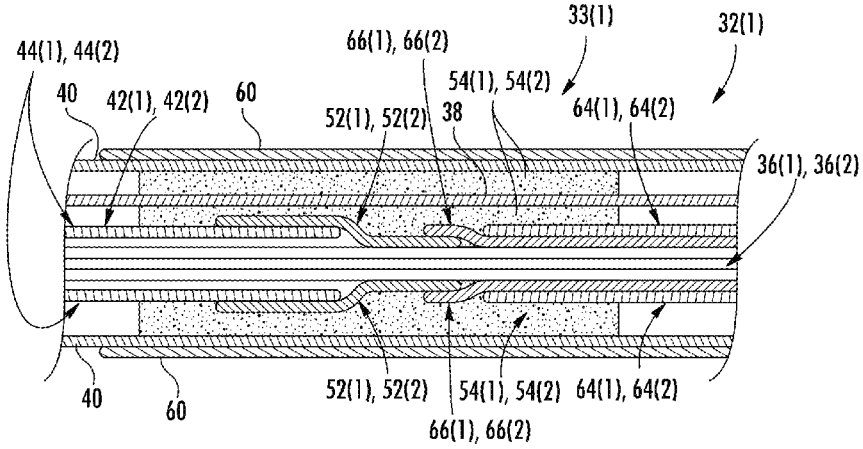
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FIG. 2B

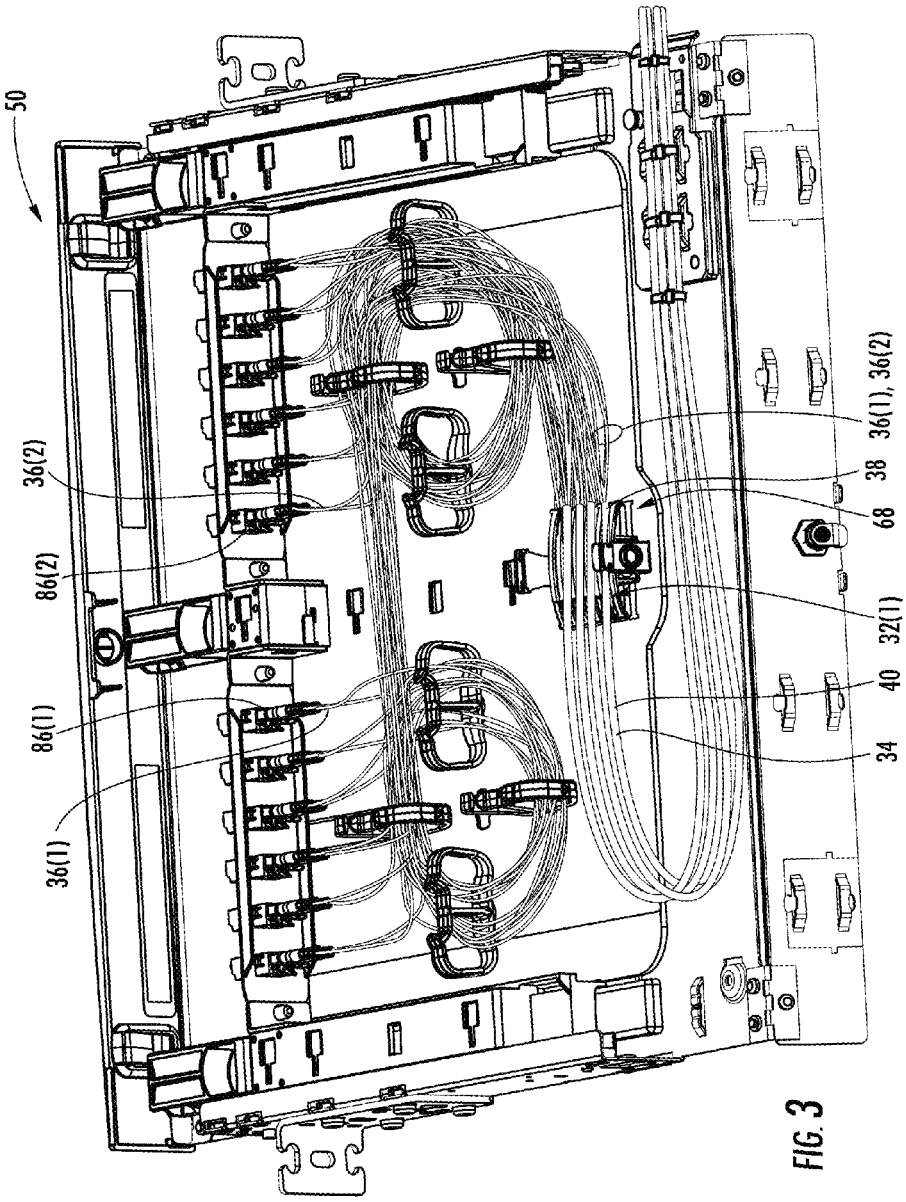
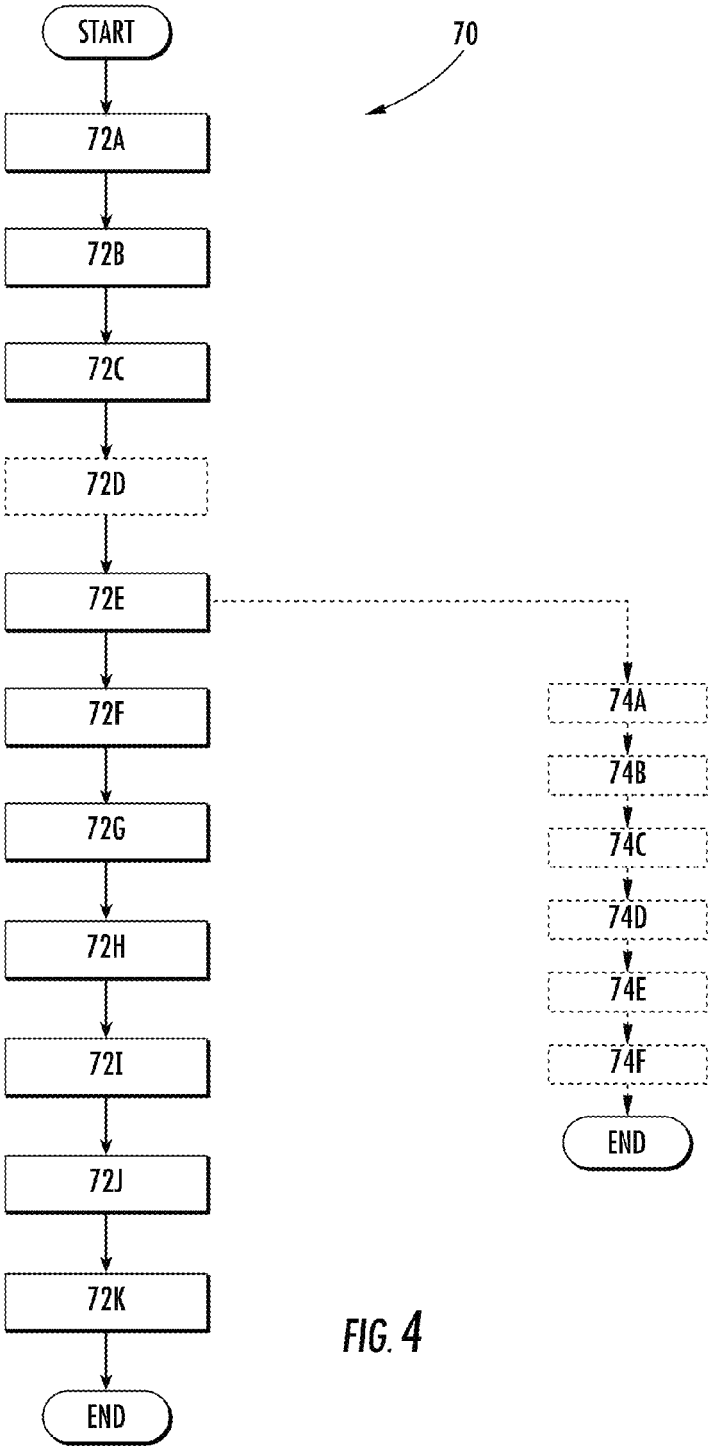


FIG. 3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72D
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72I
72J
72K
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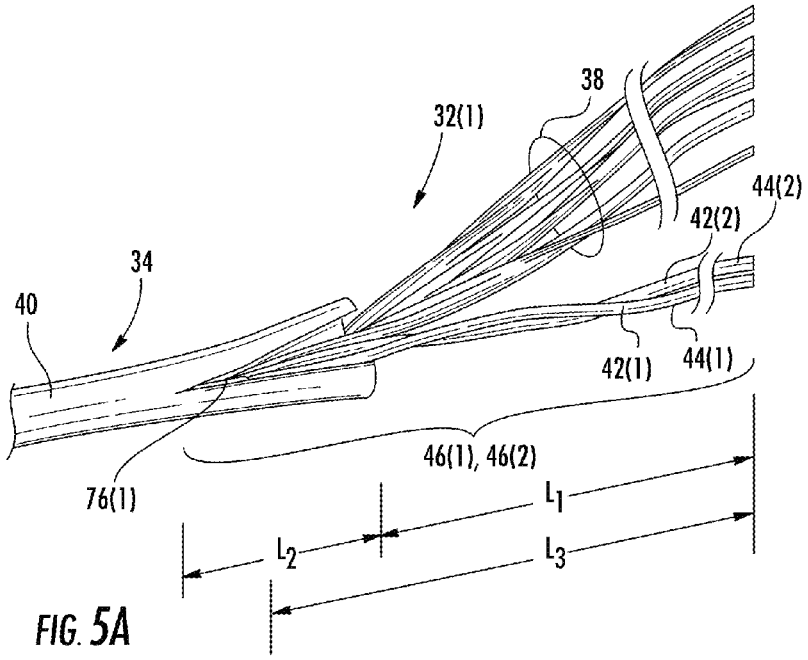
FIG. 4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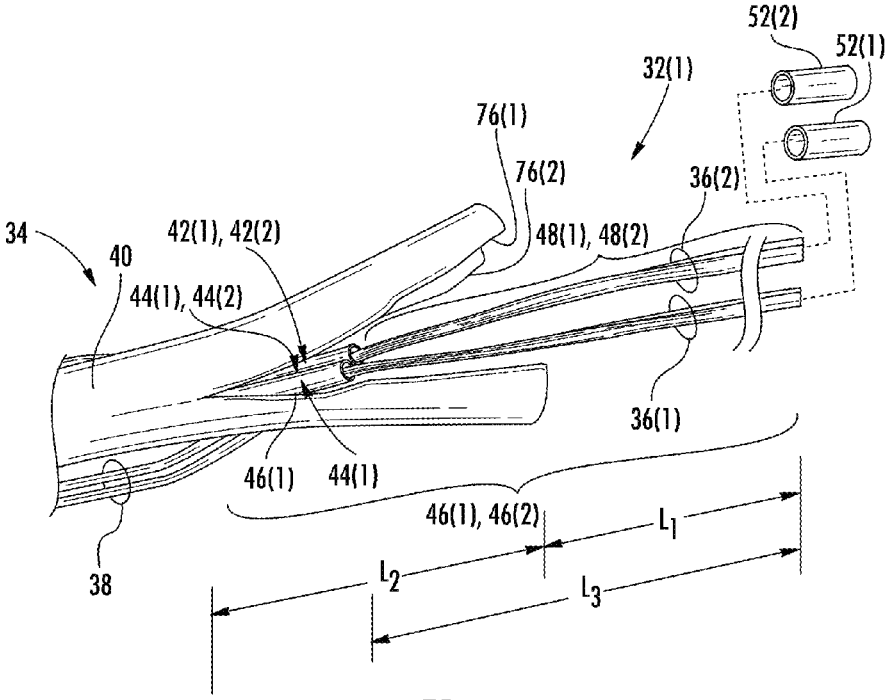
L_1
L_2
L_3

FIG. 5A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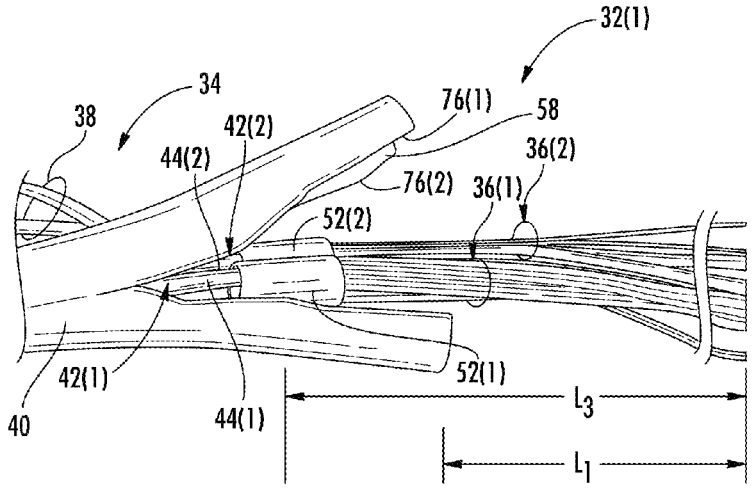
L_2
L_3

FIG. 5B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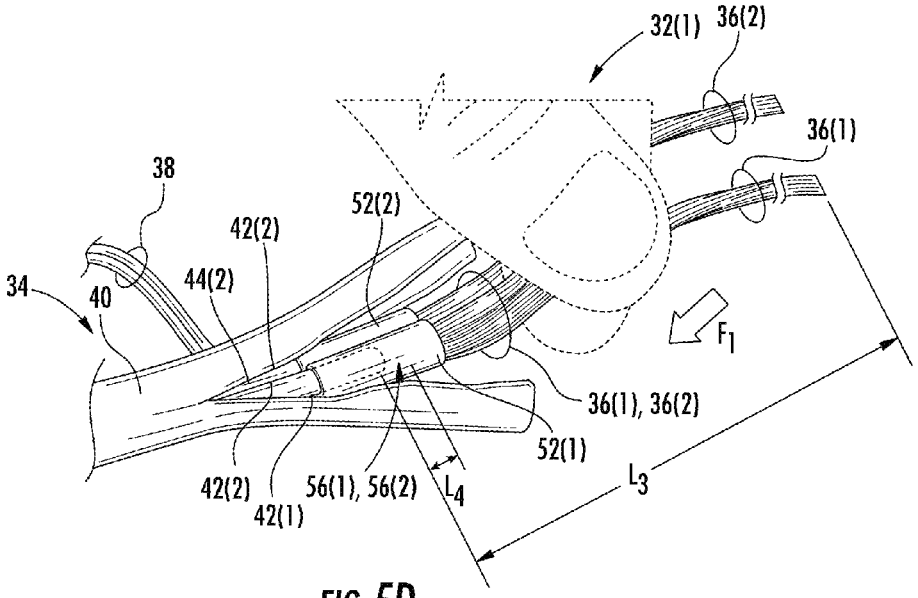
L_3
L_1

FIG. 5C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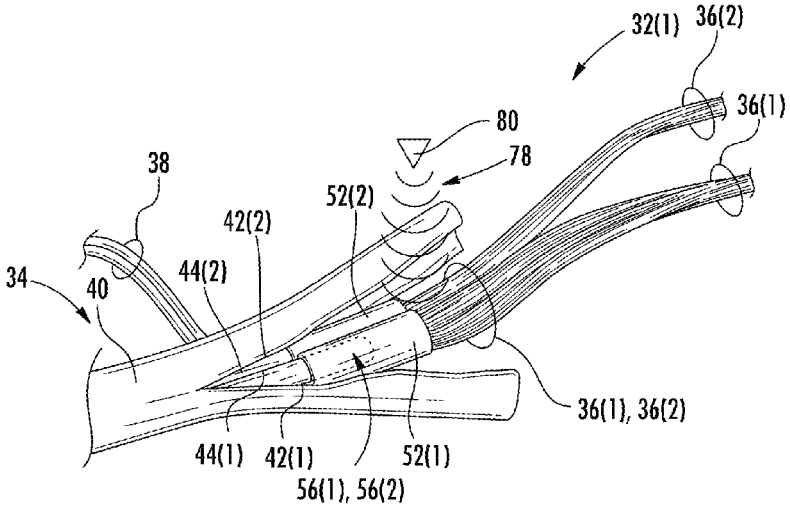
56(1), 56(2)
L_4
L_3

FIG. 5D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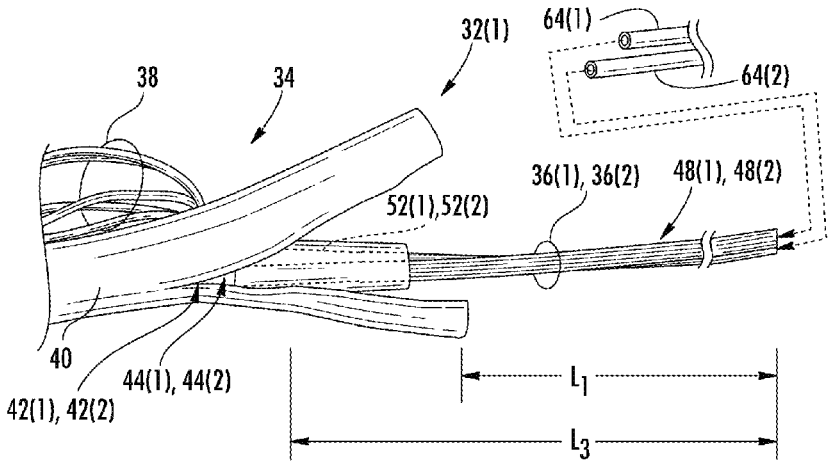
42(1)
52(1)
56(1), 56(2)

FIG. 5E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L_1
L_3

FIG. 5F

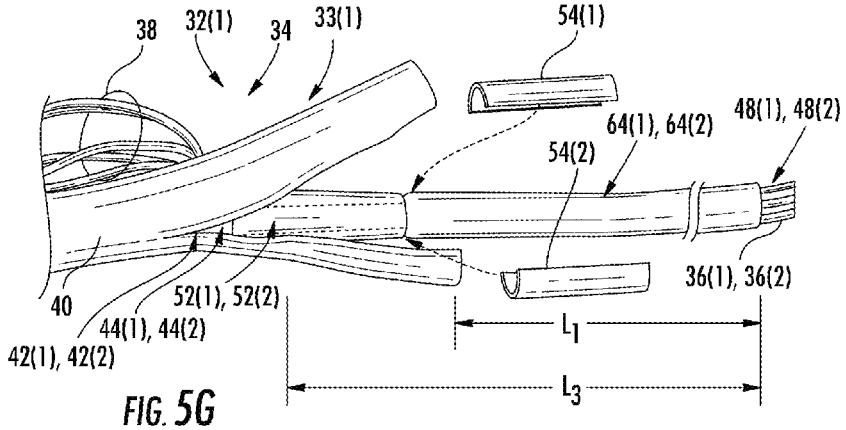

FIG. 5G

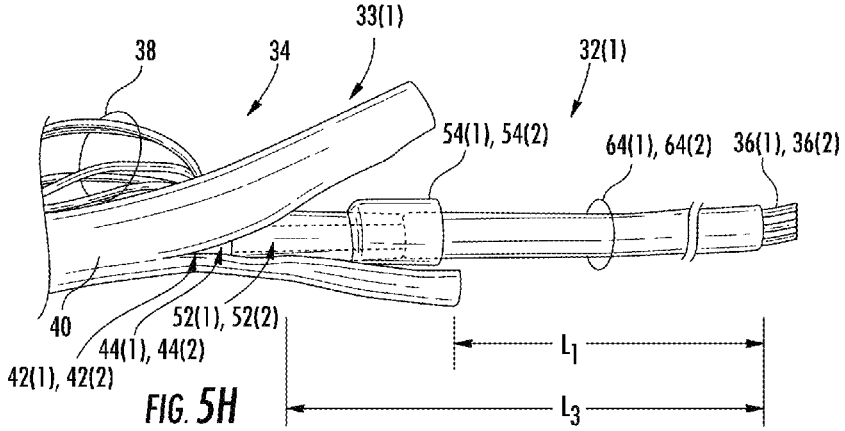

FIG. 5H

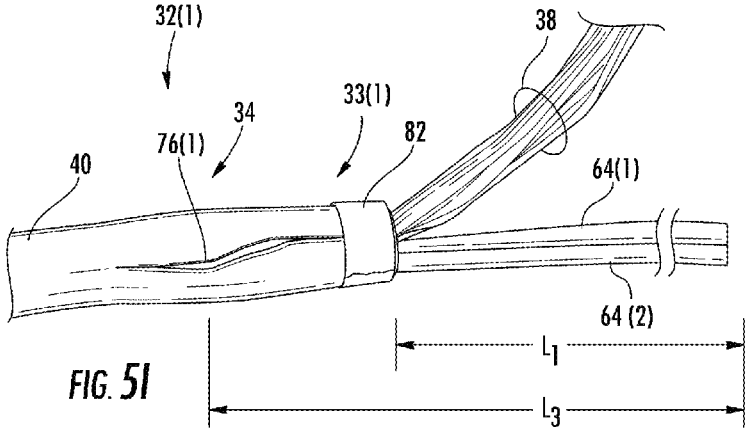

FIG. 5I

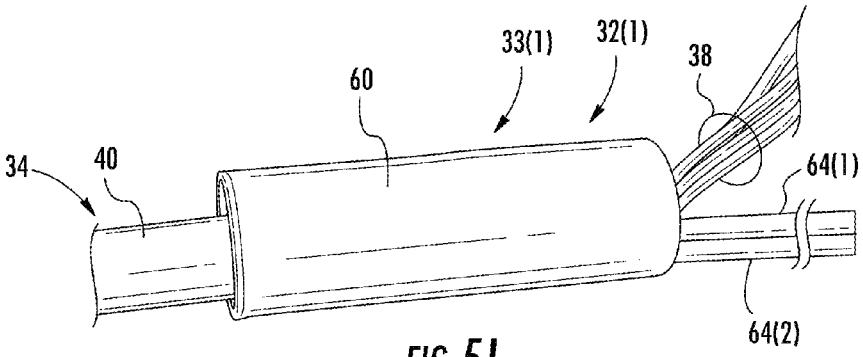

FIG. 5J

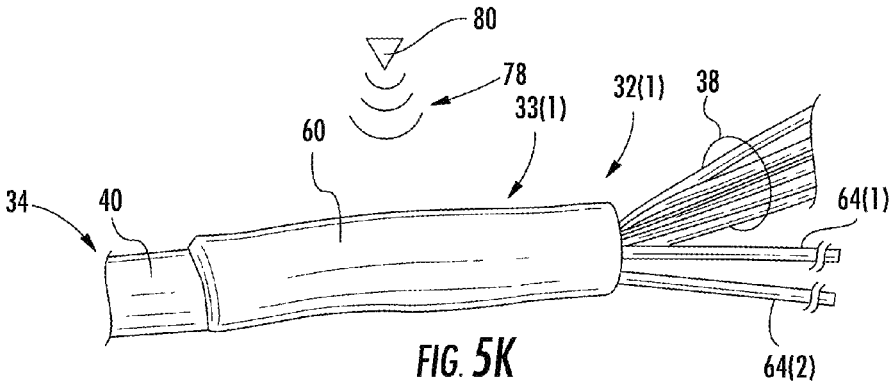

FIG. 5K

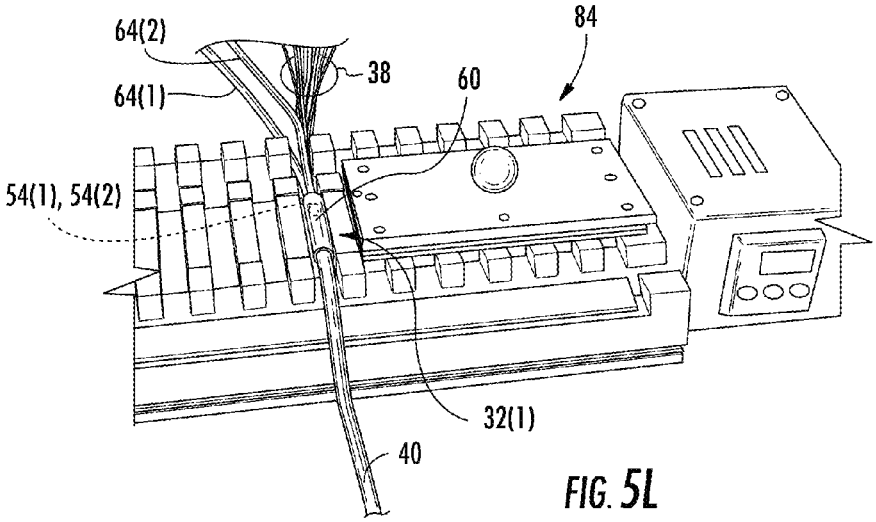

FIG. 5L

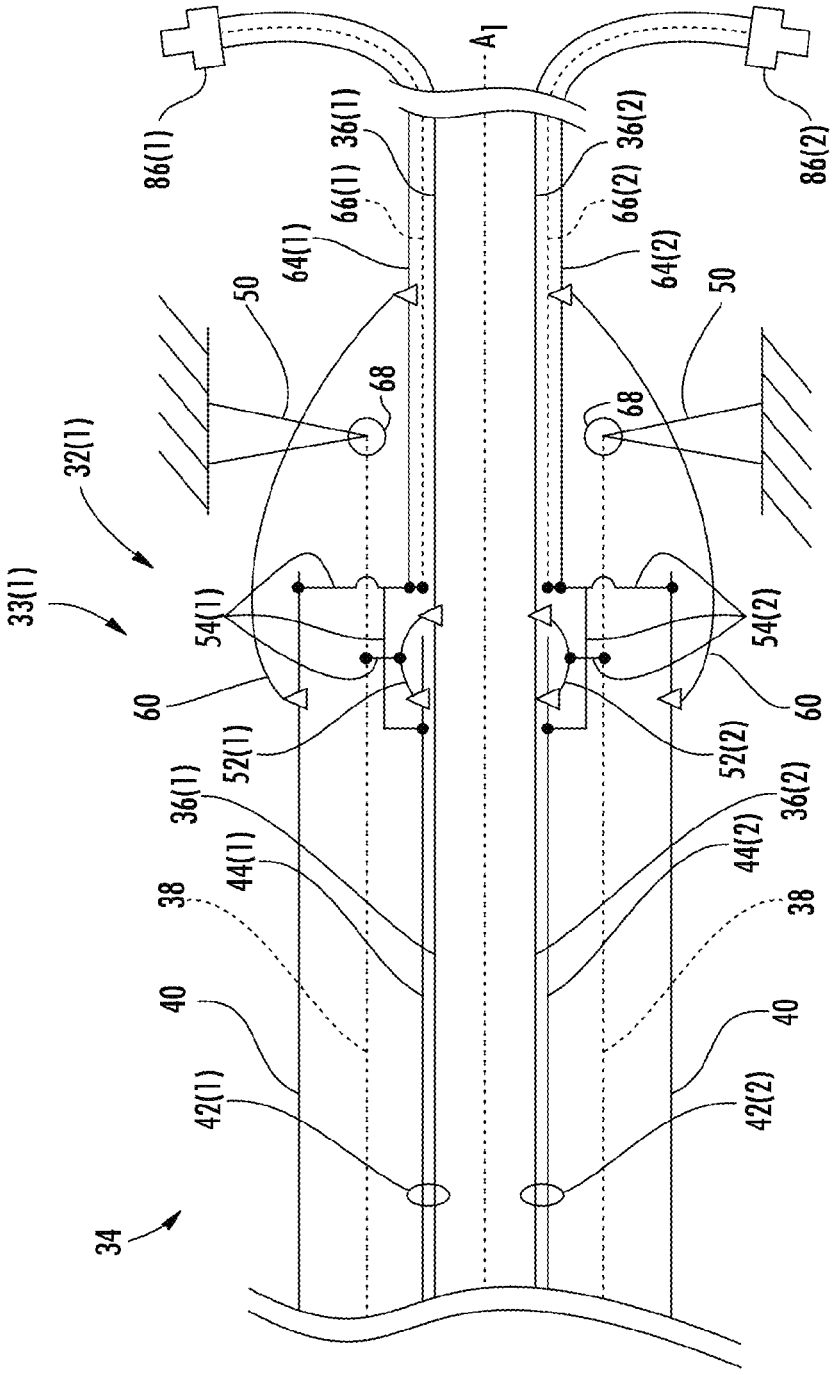
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FIG. 6

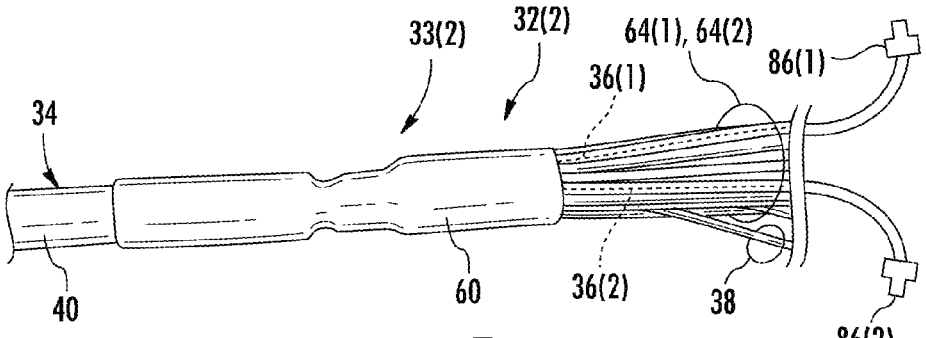


FIG. 7

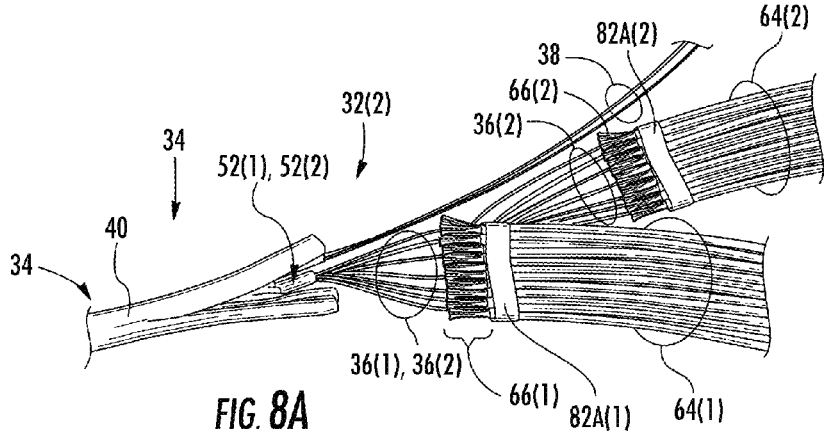


FIG. 8A

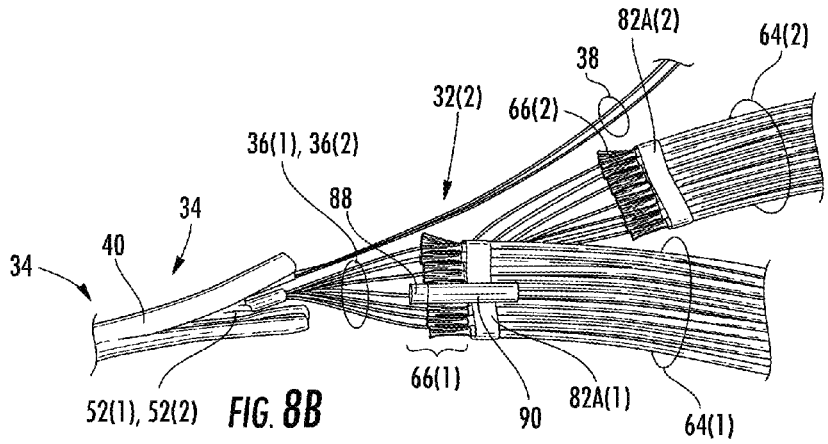


FIG. 8B

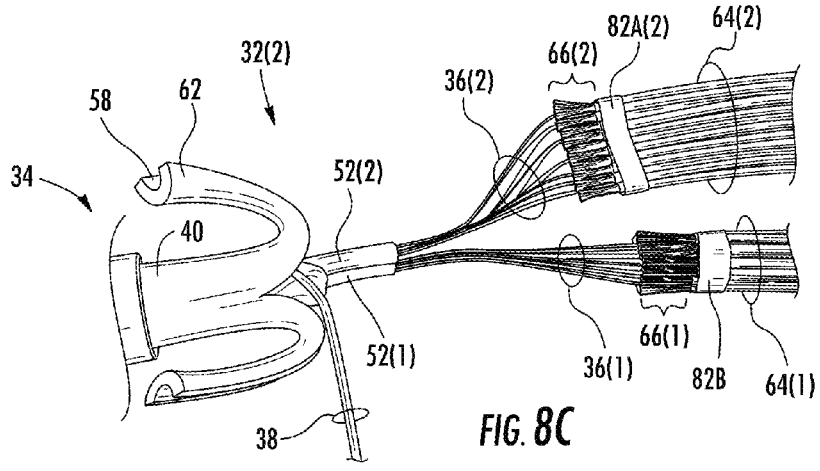


FIG. 8C

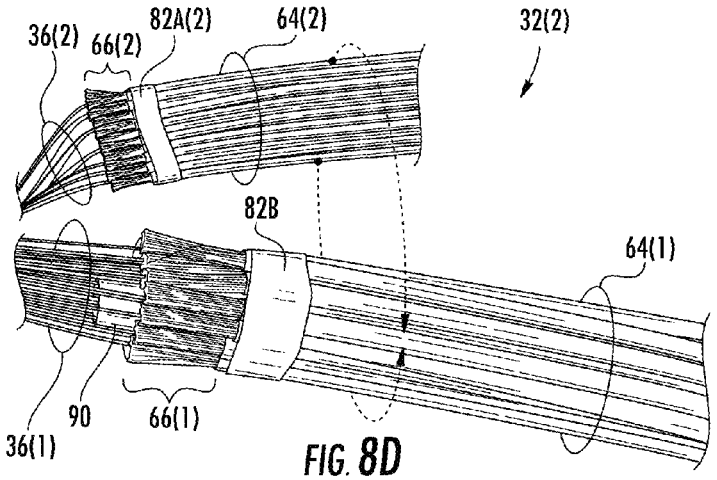


FIG. 8D

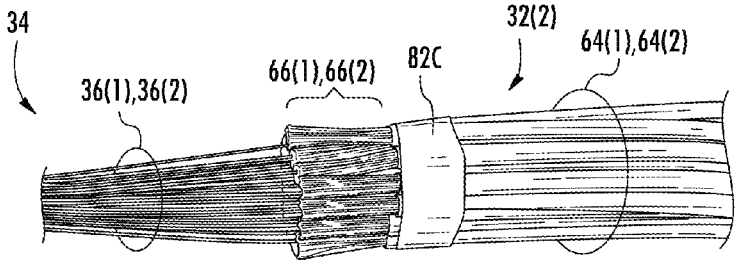
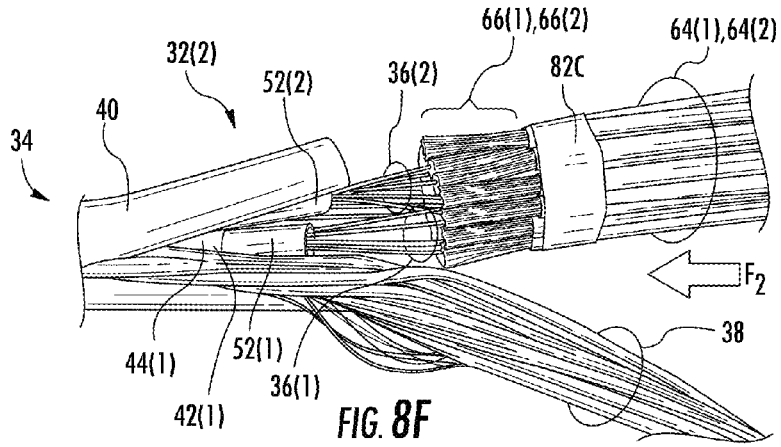


FIG. 8E



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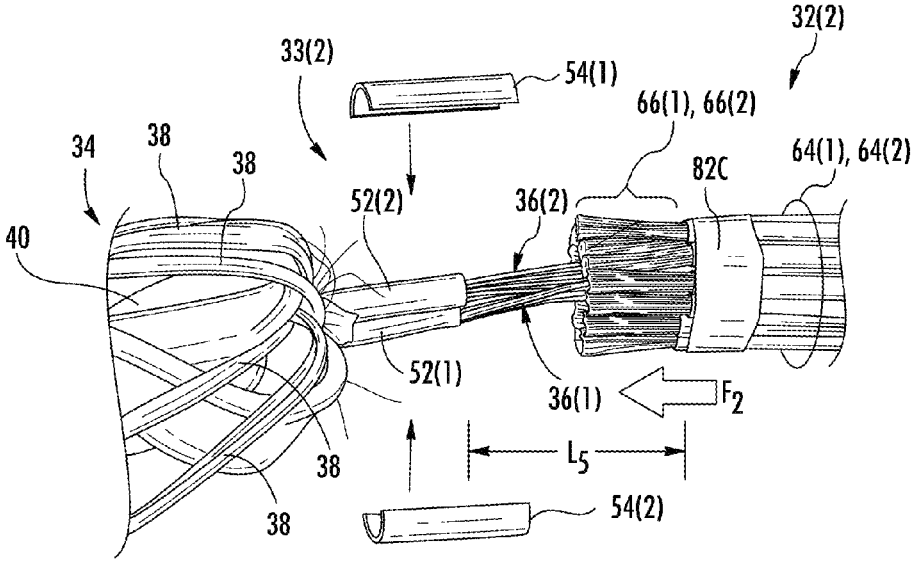
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54(2)

FIG. 8G

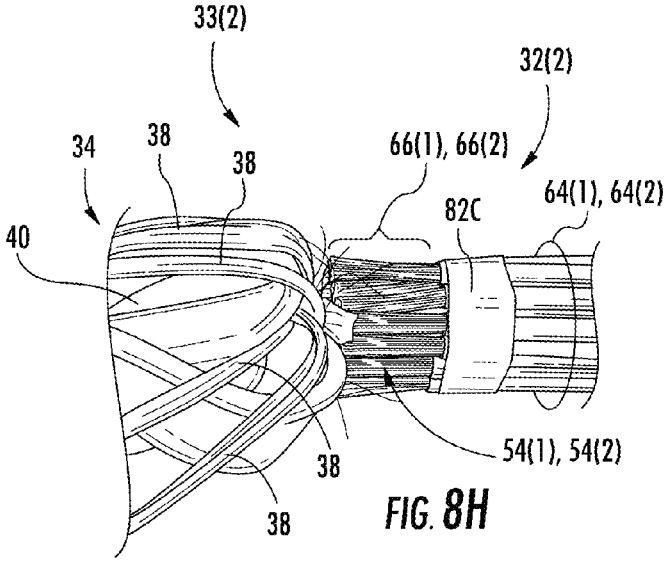
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FIG. 8H

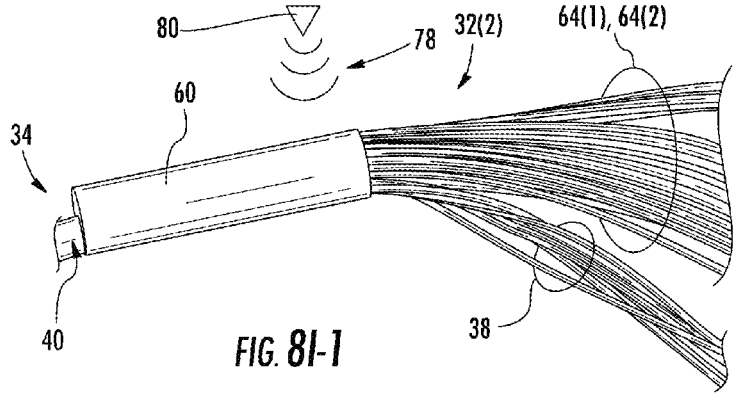

FIG. 8I-1

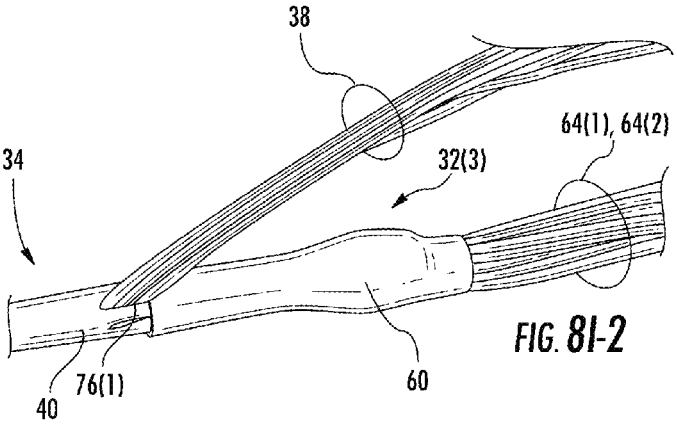

FIG. 8I-2

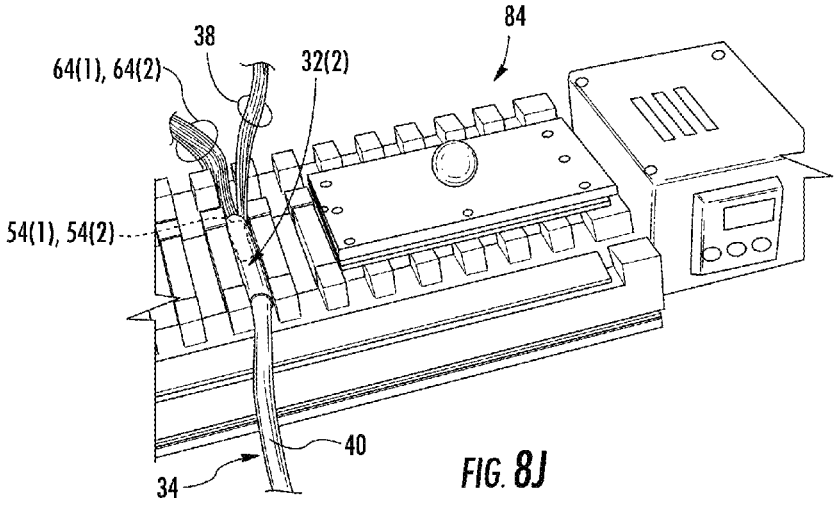

FIG. 8J

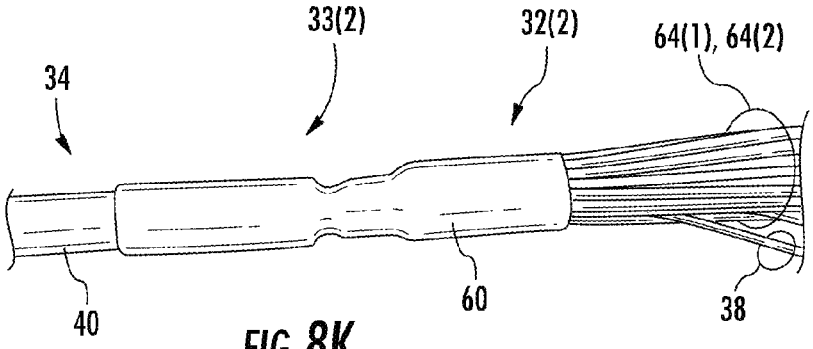

FIG. 8K

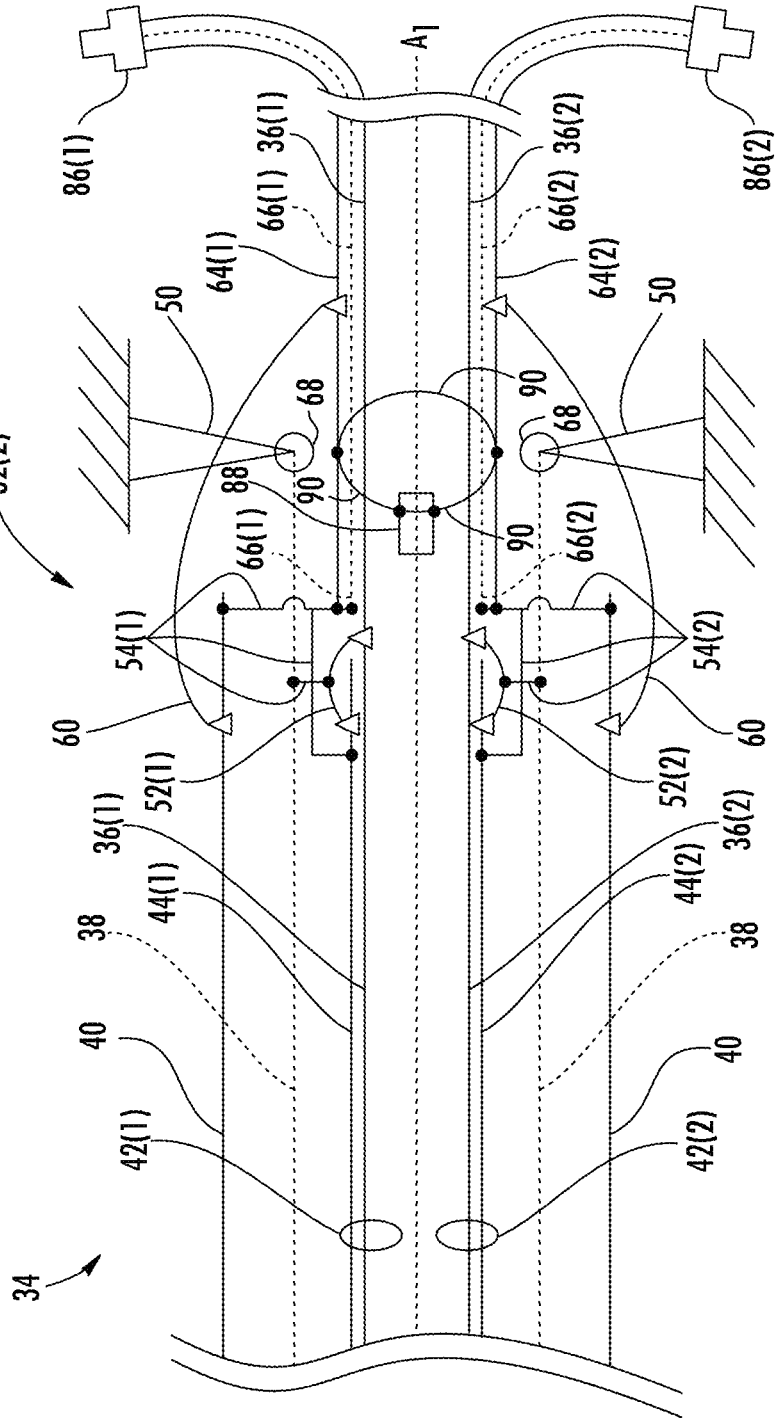
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FIG. 9

FURCATING FIBER OPTIC CABLES WITHOUT DIRECT COUPLING OF OPTICAL FIBERS TO STRENGTH MEMBERS, AND RELATED ASSEMBLIES AND METHODS

RELATED APPLICATIONS

This application claims the benefit of priority under 35 U.S.C. §119 of U.S. Provisional Application Ser. No. 61/770,692 filed on Feb. 28, 2013, the content of which is relied upon and incorporated herein by reference in its entirety.

BACKGROUND

1. Field of the Disclosure

The field of the disclosure relates to fiber optic cable furcation assemblies for splitting-out optical fibers from a fiber optic cable for establishing fiber optic connections.

2. Technical Background

In telecommunication infrastructure installations, optical fiber is increasingly being used to establish communications connections. Benefits of optical fiber include high bandwidth and low power consumption to provide for efficient communications. Optical fibers can be provided in fiber optic cables. Fiber optic cables include a cable jacket surrounding the optical fibers for protection against environmental factors that can damage the optical fibers. The fiber optic cables can be pulled to fiber optic equipment during installation to establish optical connections. The fiber optic cables may include strength members within the cable jacket, such as aramid fiber, to resist bending forces on the cable jacket, which could otherwise damage the optical fibers. The fiber optic cables are furcated to separate or "break-out" individual optical fibers from the cable jacket of the fiber optic cable to establish optical connections between the optical fibers and fiber optic components contained in the fiber optic equipment.

In this regard, FIG. **1** illustrates a conventional furcation assembly **10** that provides a furcation of a fiber optic cable **12**. When furcating a fiber optic cable **12** to create the furcation assembly **10**, a process called "break-out" may be provided. The furcation assembly **10** secures the "broken-out" optical fibers **14**(**1**)-**14**(**8**) to the cable jacket **18** and/or strength members **20**. Break-out occurs at an end portion **26** of the fiber optic cable **12** where an end portion **16** of a cable jacket **18** of the fiber optic cable **12** is removed. The furcation assembly **10** can also be installed on fiber optic equipment to secure the fiber optic cable **12** to the fiber optic equipment to prevent forces on the fiber optic cable **12** from pulling on the "broken out" optical fibers **14**(**1**)-**14**(**8**).

With continuing reference to FIG. **1**, the furcation assembly **10** includes a furcation body **22** serving as a protective enclosure for the optical fibers **14**(**1**)-**14**(**8**). The optical fibers **14**(**1**)-**14**(**8**) are bonded inside the furcation body **22** with a potting compound **24**, which may be an epoxy. During the furcating process, the "broken out" optical fibers **14**(**1**)-**14**(**8**) are inserted through the furcation body **22** so that an end **27** of the cable jacket **18**, a portion of the optical fibers **14**(**1**)-**14**(**8**) adjacent to the end **27** of the cable jacket **18**, and a portion of the strength members **20** adjacent to the end **27** of the cable jacket **18** are disposed within the furcation body **22**. The potting compound **24** is disposed in the furcation body **22** to secure the optical fibers **14**(**1**)-**14**(**8**) to the strength member **20**, the cable jacket **18**, and furcation body **22**. A seal **28** is applied to the furcation body **22** to prevent the potting compound **24** from escaping out at a bottom **30** of the furcation body **22** where the cable jacket **18** extends out of the furcation body **22**. When the potting compound **24** is cured, the optical fibers **14**(**1**)-**14**(**8**), the cable jacket **18**, and strength members **20** are secured together inside the furcation body **22** via the potting compound **24**. The furcation body **22** may then be pulled and/or installed in fiber optic equipment where the optical fibers **14**(**1**)-**14**(**8**) are terminated. The furcation body **22** may be then secured to the fiber optic equipment. In this manner, forces on the fiber optic cable **12** may be directed to fiber optic equipment (not shown) instead of the optical fibers **14**(**1**)-**14**(**8**).

Furcating a fiber optic cable **12** by use of the potting compound **24** in the furcation body **22** may result in certain issues related to manufacturing and installation. For example, small air bubbles (also called "microbubbles") may form in the potting compound **24** adjacent to the optical fibers **14**(**1**)-**14**(**8**) within the furcation body **22**. The air bubbles may cause microbends in the adjacent optical fibers **14**(**1**)-**14**(**8**) resulting in signal attenuation as the air bubbles change size with temperature and humidity. The potting compound **24** used in combination with a small interior space of the furcation body **22** may also make it difficult to control and monitor the relationship between the strength members **20** and the optical fibers **14**(**1**)-**14**(**8**) bonded together at the furcation assembly **10**. As a result, the cable forces from the strength members **20** may propagate to the optical fibers **14**(**1**)-**14**(**8**) held taut by the potting compound **24** where damage and/or attenuation may occur. Also, if the furcation body **22** has a larger outer diameter than the cable jacket **18**, the furcation body **22** is not easily pulled through increasingly smaller conduits at installation sites, and furcation alternatives that are more easily pulled would be desirable.

SUMMARY OF THE DETAILED DESCRIPTION

Embodiments disclosed herein include furcating fiber optic cables without direct coupling of optical fibers to strength members. Related methods and assemblies are also disclosed. A furcation is formed on a fiber optic cable comprised of a cable jacket surrounding strength member(s) and fiber sub-unit(s) each containing optical fiber(s). The fiber optic cable furcation "breaks-out" the optical fiber sub-units from the cable jacket so that optical connections may be established. The furcation also secures component(s) of the cable to the strength member(s) to carry cable strain. The furcation includes a shrink tube(s) to secure optical fiber(s) to their fiber sub-unit jacket(s). The shrink tube(s) is secured inside the cable jacket to secure fiber sub-unit(s) and their optical fiber(s) as part of the furcation. The strength members(s) of the fiber optic cable is also secured to the cable jacket of the fiber optic cable as part of the furcation. The shrink tube(s) prevents the optical fiber(s) of the fiber sub-unit(s) from being directly coupled to the strength member(s) in the furcation. By not directly coupling the optical fibers to the strength member(s), cable strain can be directed to the cable jacket and the fiber sub-unit jacket(s). The shrink tube(s) can also prevent or reduce micro-bubbles forming around the optical fiber(s) in the furcation that may cause optical attenuation from micro-bending occurring in the optical fiber(s).

In this regard, in one embodiment, a method of furcating a fiber optic cable is provided. The method comprises exposing an end portion of at least one fiber sub-unit and an end portion of at least one strength member from a cable jacket of a fiber optic cable. The method also comprises exposing an end portion of at least one optical fiber from an end portion of at least one fiber sub-unit jacket of the at least one fiber sub-unit. The method also comprises securing the end portion of the at least one optical fiber to the at least one fiber sub-unit jacket with at least one shrink tube. The method also comprises

securing the at least one shrink tube securing the at least one optical fiber to the at least one fiber sub-unit jacket, and the at least one strength member to the cable jacket with at least one coupling member to furcate the fiber optic cable without direct coupling of the at least one strength member to the at least one optical fiber. In this manner, the fiber optic cable furcation may direct cable strain to the cable jacket instead of to the at least one optical fiber.

In another embodiment, a fiber optic cable furcation assembly is provided. The fiber optic cable furcation assembly comprises a fiber optic cable. The fiber optic cable comprises a cable jacket, at least one strength member, and an end portion of at least one fiber sub-unit. The end portion of the at least one fiber sub-unit comprises an end portion of at least one optical fiber extending from at least one fiber sub-unit jacket of the at least one fiber sub-unit. The fiber optic cable furcation assembly also comprises a furcation provided on an end portion of the fiber optic cable. The furcation comprises at least one shrink tube securing the end portion of the at least one optical fiber to the at least one fiber sub-unit jacket. The furcation also comprises at least one coupling member securing the at least one shrink tube securing the at least one optical fiber to the at least one fiber sub-unit jacket, and the at least one strength member to the cable jacket to establish the furcation of the fiber optic cable without direct coupling of the at least one strength member to the at least one optical fiber. In this manner, the fiber optic cable furcation may be easily pulled through conduits located at installation locations.

In another embodiment a fiber optic cable furcation assembly is provided. The fiber optic cable furcation assembly comprises a fiber optic cable. The fiber optic cable comprises a cable jacket, at least one strength member, and an end portion of at least one fiber sub-unit. The end portion of the at least one fiber sub-unit comprises an end portion of at least one optical fiber extending from at least one fiber sub-unit jacket of the at least one fiber sub-unit. The fiber optic cable furcation assembly further comprises a furcation provided on an end portion of the fiber optic cable. The furcation comprises at least one shrink tube securing the end portion of the at least one optical fiber to the at least one fiber sub-unit jacket. The furcation also comprises at least one fan-out tube disposed at least partially around the at least one optical fiber and abutting against the at least one shrink tube. The furcation also comprises at least one coupling member securing the at least one fan-out tube, the at least one shrink tube securing the at least one optical fiber to the at least one fiber sub-unit jacket, and the at least one strength member to the cable jacket to establish the furcation of the fiber optic cable without direct coupling of the at least one strength member to the at least one optical fiber. The at least one coupling member is comprised of a hot melt adhesive. In this manner, micro-bubbles may be eliminated or reduced at the furcation to reduce attenuation.

Additional features and advantages will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the embodiments as described herein, including the detailed description that follows, the claims, as well as the appended drawings.

It is to be understood that both the foregoing general description and the following detailed description present embodiments, and are intended to provide an overview or framework for understanding the nature and character of the disclosure. The accompanying drawings are included to provide a further understanding, and are incorporated into and constitute a part of this specification. The drawings illustrate various embodiments, and together with the description serve to explain the principles and operation of the concepts disclosed.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is a longitudinal side view of a conventional fiber optic cable furcation assembly illustrating end portions of optical fibers extending out from a fiber optic cable jacket and furcated in a furcation body with a potting compound;

FIG. **2**A is a longitudinal side view of an exemplary fiber optic cable furcation assembly including optical fibers of fiber sub-units of a fiber optic cable secured to fiber sub-unit jackets of the fiber sub-units with shrink tubes without direct coupling of the optical fibers to strength members;

FIG. **2**B a sectional close-up view of the fiber optic cable furcation of FIG. **2**A illustrating the coupling member and one of the shrink tubes;

FIG. **3** is a top perspective view of the fiber optic cable furcation assembly of FIG. **2**B installed in an exemplary fiber optic equipment;

FIG. **4** is a flowchart diagram of an exemplary process for furcating an end portion of a fiber optic cable without direct coupling of the optical fibers to strength members;

FIG. **5**A is a side longitudinal view of the cable jacket of the fiber optic cable of FIG. **2**B cut and split to expose an end portion of the fiber sub-units from the cable jacket to form the fiber optic cable furcation of FIG. **2**A;

FIG. **5**B is a side longitudinal view of the partially assembled fiber optic cable furcation assembly of FIG. **5**A illustrating the optical fibers being exposed from sub-unit jackets and shrink tubes provided, but detached, for later assembly;

FIG. **5**C is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **5**B, with at least shrink tubes each disposed around the fiber sub-unit jackets and the optical fibers, to secure the optical fibers to the fiber sub-unit jackets without direct coupling to the strength member of the fiber optic cable;

FIG. **5**D is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **5**C illustrating extra fiber length (EFL) of the optical fibers being pushed back into the fiber sub-unit jackets;

FIG. **5**E is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **5**D depicting the optical fibers being secured to the fiber sub-unit jackets by exposing the shrink tubes to heat energy;

FIGS. **5**F and **5**G are longitudinal side views of the partially assembled fiber optic cable furcation assembly of FIG. **5**E with at least one fan-out tube being at least partially disposed around an end portion of the optical fibers and adjacent to the shrink tubes;

FIG. **5**H is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **5**G with the coupling members disposed adjacent to the shrink tubes;

FIG. **5**I is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **5**H illustrating the cable jacket being disposed around the coupling members and tape holding the cable jacket in place;

FIG. **5**J is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **5**I illustrating at least one outer shrink tube being disposed around the cable jacket;

FIG. **5**K is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **5**J

illustrating the outer shrink tube being secured to the cable jacket with the application of heat energy to the outer shrink tube;

FIG. **5**L is a top perspective view of the partially assembled fiber optic cable furcation assembly of FIG. **5**K disposed in a heater illustrating the coupling member securing the cable jacket to the shrink tubes, and the strength member;

FIG. **6** is a schematic diagram illustrating the exemplary relationships between components of the fiber optic cable furcation of FIG. **2**A;

FIG. **7** is a longitudinal side view of another exemplary fiber optic cable furcation assembly including optical fibers of fiber sub-units of a fiber optic cable secured to fiber sub-unit jackets of the fiber sub-units with shrink tubes, the shrink tubes are disposed without direct coupling of the optical fibers to strength members, similar to the fiber optic cable furcation assembly of FIG. **2**A, but including fan-out tubes arranged using a wrapping technique;

FIG. **8**A is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **7** illustrating the optical fibers of the partially assembled fiber cable assembly of FIG. **5**F being disposed within the fan-out tubes;

FIG. **8**B is a longitudinal side view of the fiber optic cable furcation assembly of FIG. **8**A in a partially assembled condition to illustrate a radial holding member being disposed adjacent to one portion of the fan-out tubes associated with one of the fiber sub-units;

FIG. **8**C is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **8**B illustrating the one portion of the fan-out tubes being wrapped about the radial holding member;

FIG. **8**D is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **8**C illustrating a second portion of the fan-out tubes being wrapped about the one portion of the fan-out tube;

FIG. **8**E is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **8**D illustrating the second portion of the at least one fan-out tube wrapped about the one portion of the fan-out tubes;

FIG. **8**F is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **8**E illustrating the fan-out tubes being further disposed around the optical fibers;

FIG. **8**G is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **8**F illustrating the at least one coupling member being disposed around the shrink tubes;

FIG. **8**H is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **8**G illustrating the fan-out tubes being disposed adjacent to the shrink tubes;

FIG. **8**I-**1** is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. **8**H illustrating the outer shrink tube being disposed over the fan-out tubes and the cable jacket, and heat being applied to the at least one outer shrink tube to secure the outer shrink tube to the fan-out tubes and the cable jacket;

FIG. **8**I-**2** is a side view of another exemplary fiber optic cable furcation assembly illustrating the strength members exiting from the split cut in the cable jacket and the outer shrink tube secured around the partially assembled fiber optic cable furcation of FIG. **8**H;

FIG. **8**J is a top perspective view of the partially assembled fiber optic cable furcation assembly of FIG. **8**I-**1** disposed in a heater to illustrate the coupling member securing the cable jacket to the optical fibers, the shrink tubes, and the fan-out tubes;

FIG. **8**K is a side view of the completed fiber optic cable furcation after removal from the heater of FIG. **8**J; and

FIG. **9** is a schematic diagram of the fiber optic cable furcation assembly of FIG. **8**K with the strength members providing strain relief to the fiber optic cable by being attached to fiber optic equipment and the optical fibers having fiber optic connectors installed and ready for termination.

DETAILED DESCRIPTION

Reference will now be made in detail to the embodiments, examples of which are illustrated in the accompanying drawings, in which some, but not all embodiments are shown. Indeed, the concepts may be embodied in many different forms and should not be construed as limiting herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Whenever possible, like reference numbers will be used to refer to like components or parts.

Embodiments disclosed herein include furcating fiber optic cables without direct coupling of optical fibers to strength members. Related methods and assemblies are also disclosed. A furcation is formed on a fiber optic cable comprised of a cable jacket surrounding strength member(s) and fiber sub-unit(s) each containing optical fiber(s). The fiber optic cable furcation "breaks-out" the optical fiber sub-units from the cable jacket so that optical connections may be established. The furcation also secures component(s) of the cable to the strength member(s) to carry cable strain. The furcation includes a shrink tube(s) to secure the optical fiber(s) to their fiber sub-unit jacket(s). The shrink tube(s) is secured inside the cable jacket to secure fiber sub-unit(s) and their optical fiber(s) as part of the furcation. The strength members(s) of the fiber optic cable is also secured to the cable jacket of the fiber optic cable as part of the furcation. The shrink tube(s) prevents the optical fiber(s) of the fiber sub-unit(s) from being directly coupled to the strength member(s) in the furcation. By not directly coupling the optical fibers to the strength member(s), cable strain can be directed to the cable jacket and the fiber sub-unit jacket(s). The shrink tube(s) can also prevent or reduce micro-bubbles forming around the optical fiber(s) in the furcation that may cause optical attenuation from micro-bending occurring in the optical fiber(s).

In this regard, FIGS. **2**A and **2**B are a longitudinal side view and a sectional close-up view, respectively, of an exemplary fiber optic cable furcation assembly **32**(**1**) for a fiber optic cable **34** comprising a fiber optic cable **34** and a furcation **33**(**1**). As will be discussed in more detail below, the optical fibers **36**(**1**), **36**(**2**) of the fiber optic cable **34** are secured in the fiber optic cable furcation assembly **32**(**1**) without direct coupling of the optical fibers **36**(**1**), **36**(**2**) to the strength member **38** of the fiber optic cable **34**. The fiber optic cable **34** on which the fiber optic cable furcation assembly **32**(**1**) is formed includes a cable jacket **40** and at least one fiber sub-unit **42**(**1**), **42**(**2**) at least partially disposed within the cable jacket **40**. The fiber sub-units **42**(**1**), **42**(**2**) comprise at least one fiber sub-unit jacket **44**(**1**), **44**(**2**) and the optical fibers **36**(**1**), **36**(**2**) at least partially disposed within the fiber sub-unit jackets **44**(**1**), **44**(**2**). The cable jacket **40** protects the contents of the fiber optic cable **34** from environmental factors and the fiber sub-unit jackets **44**(**1**), **44**(**2**) resist bending and thereby protect the optical fibers **36**(**1**), **36**(**2**) from bends and kinks within the cable jacket **40**.

With continuing reference to FIGS. **2**A and **2**B, the fiber optic cable furcation assembly **32**(**1**) serves to break-out the individual ones of the optical fibers **36**(**1**), **36**(**2**) so that optical connections may be established. The cable jacket **40** may be stripped a distance L_1 and then split a distance L_2 to collectively expose at least one end portion **46**(**1**), **46**(**2**) of the fiber sub-units **42**(**1**), **42**(**2**) from the cable jacket **40**. Also, the fiber sub-unit jackets **44**(**1**), **44**(**2**) may be stripped a distance L_3 to expose at least one end portion **48**(**1**), **48**(**2**) of the optical fibers **36**(**1**), **36**(**2**). Thereby the end portion **46**(**1**), **46**(**2**) of the fiber sub-units **42**(**1**), **42**(**2**) comprises the end portion **48**(**1**), **48**(**2**) of the optical fibers **36**(**1**), **36**(**2**) extending from the fiber sub-unit jackets **44**(**1**), **44**(**2**) of the fiber sub-units **42**(**1**), **42**(**2**). In this manner, the individual ones of the optical fibers **36**(**1**), **36**(**2**) may break-out of the cable jacket **40** of the fiber optic cable **34** to be individually connected.

With continuing reference to FIGS. **2**A and **2**B, the fiber optic cable furcation assembly **32**(**1**) also serves to protect the optical fibers **36**(**1**), **36**(**2**) from cable strain F_S as they extend from the cable jacket **40** by attaching various components of the fiber optic cable **34** together. In this manner, if one or more components of the fiber optic cable **34** may be subjected to the cable strain F_S, then the cable strain F_S may be collectively conveyed to the strength member **38** of the fiber optic cable **34** at the fiber optic cable furcation assembly **32**(**1**) and directed to fiber optic equipment **50** attached to the strength member **38**. By directing the cable strain to the fiber optic equipment **50** (FIG. **3**), the fiber optic cable furcation assembly **32**(**1**) prevents the cable strain F_S from propagating to the individual ones of the optical fibers **36**(**1**), **36**(**2**) where damage or attenuation may occur.

In order to secure the various components of the fiber optic cable **34** together, the furcation **33**(**1**) of the fiber optic cable furcation assembly **32**(**1**) comprises at least one shrink tube **52**(**1**), **52**(**2**) and at least one coupling member **54**(**1**), **54**(**2**). The shrink tubes **52**(**1**), **52**(**2**) enable the optical fibers **36**(**1**), **36**(**2**) to be secured within the fiber optic cable furcation assembly **32**(**1**) without direct coupling to the strength member **38**. Specifically, the shrink tubes **52**(**1**), **52**(**2**) secure the optical fibers **36**(**1**), **36**(**2**) to the fiber sub-unit jackets **44**(**1**), **44**(**2**). The fiber sub-unit jackets **44**(**1**), **44**(**2**) provide the securing required to keep the optical fibers **36**(**1**), **36**(**2**) secured at the furcation **33**(**1**) to prevent cable strain from propagating along the optical fibers **36**(**1**), **36**(**2**) as they exit the cable jacket **40**. By not directly coupling the optical fibers **36**(**1**), **36**(**2**) to the strength member **38**, cable strain can be directed to the cable jacket **40** and the fiber sub-unit jackets **44**(**1**), **44**(**2**).

The shrink tubes **52**(**1**), **52**(**2**) may use a mechanical lock (or friction) to be secured to the fiber sub-unit jackets **44**(**1**), **44**(**2**) and the optical fibers **36**(**1**), **36**(**2**). To supplement the mechanical lock (or friction) and with continued reference to FIGS. **2**A and **2**B, the shrink tubes **52**(**1**), **52**(**2**) may include one or more adhesive and/or cohesive materials to form chemical adhesive or cohesive bonds with the fiber sub-unit jackets **44**(**1**), **44**(**2**) and the optical fibers **36**(**1**), **36**(**2**). In this manner, the fiber sub-unit jackets **44**(**1**), **44**(**2**) may be secured to the optical fibers **36**(**1**), **36**(**2**).

Moreover, securing of the fiber sub-unit jackets **44**(**1**), **44**(**2**) to the optical fibers **36**(**1**), **36**(**2**) makes possible precise disposition of extra fiber length (EFL) **56**(**1**), **56**(**2**) of the optical fibers **36**(**1**), **36**(**2**), respectively, within the fiber sub-unit jackets **44**(**1**), **44**(**2**). The EFL **56**(**1**), **56**(**2**) protects against damage to the optical fibers **36**(**1**), **36**(**2**) so that when the fiber optic cable **34** is subject to tension from the cable strain F_S, the EFL **56**(**1**), **56**(**2**) may provide extra slack to reduce potentially damaging tension on the optical fibers **36**(**1**), **36**(**2**).

With continued reference to FIGS. **2**A and **2**B, it is also noted that securing the fiber sub-unit jackets **44**(**1**), **44**(**2**) to the optical fibers **36**(**1**), **36**(**2**) may also reduce or eliminate attenuation-causing micro-bends in the optical fibers **36**(**1**), **36**(**2**) as a result of micro-bubbles. The strength members **38** and the coupling members **54**(**1**), **54**(**2**) are not directly coupled to the optical fibers **36**(**1**), **36**(**2**), because the optical fibers **36**(**1**), **36**(**2**) are instead secured to the fiber sub-unit jackets **44**(**1**), **44**(**2**). The strength members **38** have been identified as a source of micro-bubbles when encapsulated within potting compounds because air sometimes is trapped at the surface of the strength members **38**. When the micro-bubbles are located in close proximity to the optical fibers **36**(**1**), **36**(**2**) the micro-bubbles may become attenuation-causing, because the micro-bubbles push and pull on the optical fibers **36**(**1**), **36**(**2**) causing micro-bends in the optical fibers **36**(**1**), **36**(**2**) with changes in temperature. By securing the optical fibers **36**(**1**), **36**(**2**) to the fiber sub-unit jackets **44**(**1**), **44**(**2**) instead of to the strength members **38** via the coupling members **54**(**1**), **54**(**2**), the optical fibers **36**(**1**), **36**(**2**) can be better isolated from the sources of micro-bubbles and thus attenuation from micro-bends may be reduced.

With continued reference to FIGS. **2**A and **2**B, the coupling members **54**(**1**), **54**(**2**) of the fiber optic cable furcation assembly **32**(**1**) also serve to attach various components of the fiber optic cable **34** within the fiber optic cable furcation assembly **32**(**1**). The coupling members **54**(**1**), **54**(**2**) secure the shrink tubes **52**(**1**), **52**(**2**) to an inner surface **58** of the cable jacket **40** of the fiber optic cable **34**. The coupling members **54**(**1**), **54**(**2**) may include one or more adhesive and/or cohesive materials to form chemical adhesion or cohesion between the inner surface **58** of the cable jacket **40** and the shrink tubes **52**(**1**), **52**(**2**). The coupling members **54**(**1**), **54**(**2**) may also couple the strength member **38** of the fiber optic cable **34** to the inner surface **58** of the cable jacket **40**. In this manner, the shrink tubes **52**(**1**), **52**(**2**) may secure the optical fibers **36**(**1**), **36**(**2**) to the fiber sub-unit jackets **44**(**1**), **44**(**2**) instead of coupling the optical fibers **36**(**1**), **36**(**2**) to the strength member **38** with the coupling members **54**(**1**), **54**(**2**). Accordingly, attenuation-causing micro-bubbles may be avoided adjacent to the optical fibers **36**(**1**), **36**(**2**).

In order to add structural strength to the fiber optic cable furcation assembly **32**(**1**), the fiber optic cable furcation assembly **32**(**1**) may also include at least one outer shrink tube **60** secured around the cable jacket **40** and the shrink tubes **52**(**1**), **52**(**2**). The outer shrink tube **60** may use a mechanical lock, friction, cohesive bond, and/or adhesive bond to be secured to an outer surface **62** of the cable jacket **40**. The outer shrink tube **60** may supplement the protective function of the cable jacket **40** at the fiber optic cable furcation assembly **32**(**1**).

The optical fibers **36**(**1**), **36**(**2**) may need protection from environmental factors as they extend away from the cable jacket **40**. To provide protection, the fiber optic cable furcation assembly **32**(**1**) may also include at least one fan-out tube **64**(**1**), **64**(**2**) at least partially disposed around the end portions **48**(**1**), **48**(**2**) of the optical fibers **36**(**1**), **36**(**2**). The fan-out tubes **64**(**1**), **64**(**2**) may also be disposed adjacent to the shrink tubes **52**(**1**), **52**(**2**) to provide protection from cable strain, temperature, and humidity beginning from the shrink tubes **52**(**1**), **52**(**2**) and extending out from the cable jacket **40**. The fan-out tubes **64**(**1**), **64**(**2**) may also, by being adjacently located to the shrink tubes **52**(**1**), **52**(**2**), prevent the optical fibers **36**(**1**), **36**(**2**) from being exposed to the strength mem-

ber **38**, so the strength member **38** is not directly coupled to the optical fibers **36**(**1**), **36**(**2**) at the furcation **33**(**1**).

The fiber optic cable furcation assembly **32**(**1**) may include means to secure the fan-out tubes **64**(**1**), **64**(**2**) to the other components of the fiber optic cable furcation assembly **32**(**1**). The coupling members **54**(**1**), **54**(**2**) may secure the fan-out tubes **64**(**1**), **64**(**2**) to the cable jacket **40**. The outer shrink tube **60** may also secure the fan-out tubes **64**(**1**), **64**(**2**) to the cable jacket **40**.

The optical fibers **36**(**1**), **36**(**2**) may need protection from tension as they extend from the cable jacket **40**. At least one fan-out tube strength member **66**(**1**), **66**(**2**) may be included as part of the fan-out tubes **64**(**1**), **64**(**2**) of the fiber optic cable furcation assembly **32**(**1**). The fan-out tube strength members **66**(**1**), **66**(**2**) may be secured to the cable jacket with the coupling members **54**(**1**), **54**(**2**). In this manner, the optical fibers **36**(**1**), **36**(**2**) extending from the cable jacket may be protected by the fiber optic cable furcation assembly **32**(**1**).

In summary, the fiber optic cable furcation assembly **32**(**1**) depicted in FIGS. **2**A and **2**B comprises the fiber optic cable **34** and the furcation **33**(**1**) for breaking out the optical fibers **36**(**1**), **36**(**2**) from the cable jacket **40** so they may be independently terminated to establish fiber optic connections. The furcation **33**(**1**) comprises the shrink tubes **52**(**1**), **52**(**2**) and the coupling members **54**(**1**), **54**(**2**). The shrink tubes **52**(**1**), **52**(**2**) secure the optical fibers **36**(**1**), **36**(**2**) to their fiber sub-unit jackets **44**(**1**), **44**(**2**). The shrink tubes **52**(**1**), **52**(**2**) are also secured to the cable jacket **40** of the fiber optic cable **34** as part of the furcation **33**(**1**). By not directly coupling the optical fibers **36**(**1**), **36**(**2**) to the strength member **38**, cable strain can be directed to the cable jacket **40** and the fiber sub-unit jackets **44**(**1**), **44**(**2**). The shrink tubes **52**(**1**), **52**(**2**) can also prevent or reduce micro-bubbles forming around the optical fibers **36**(**1**), **36**(**2**) in the furcation **33**(**1**) that may cause optical attenuation from micro-bending occurring in the optical fibers **36**(**1**), **36**(**2**).

The fiber optic cable furcation assembly **32**(**1**) formed on the fiber optic cable **34** can be secured to fiber optic equipment **50** to direct cable strain F_S away from the optical fibers as they extend from the cable jacket **40**. In this regard, FIG. **3** is a top perspective view of the fiber optic cable **34** including the fiber optic cable furcation assembly **32**(**1**) of FIG. **2**A installed on exemplary fiber optic equipment **50**. The fiber optic cable furcation assembly **32**(**1**) may be attached to the fiber optic equipment **50** using the strength member **38** secured to a portion **68** of the fiber optic equipment **50** with, for example, a fastener (not shown). The fiber optic cable furcation assembly **32**(**1**) may allow optical fibers **36**(**1**), **36**(**2**) to exit the cable jacket **40** at the fiber optic cable furcation assembly **32**(**1**) and terminate independently.

It is noted that the strength member **38** is the preferred cable strain bearing component within the fiber optic cable **34**. The strength member **38** comprises a strong tensile-resistant material, for example, a para-aramid synthetic fiber. By placing the cable jacket **40** in abutment with the coupling members **54**(**1**), **54**(**2**) and the strength member **38**, a more effective bond may be formed with the cable jacket **40** to direct cable strain to the cable jacket **40** and away from the optical fibers **36**(**1**), **36**(**2**).

Now that the fiber optic cable furcation assembly **32**(**1**) has been introduced above, an exemplary process **70** to furcate the fiber optic cable **34** will be discussed below where the optical fibers **36**(**1**), **36**(**2**) of the fiber optic cable **34** are secured in the fiber optic cable furcation assembly **32**(**1**) without direct coupling of the optical fibers **36**(**1**), **36**(**2**) to the strength member **38** of the fiber optic cable **34**. In this regard, FIG. **4** provides a flowchart diagram illustrating an exemplary process **70** that may be employed to furcate the fiber optic cable **34**. The flowchart diagram includes blocks **72**A-**72**K to describe the exemplary process **70**, and blocks **74**A-**74**F are included to describe an optional embodiment. Blocks which are optional are depicted in broken lines for convenient reference. The terminology and reference characters introduced above will be utilized in the related discussion below for continuity, clarity and conciseness.

FIG. **5**A is a side longitudinal view of the fiber optic cable **34** provided at the beginning of the exemplary process **70** (Block **72**A of FIG. **4**). The cable jacket **40** may be stripped the distance L_1 and then split the distance L_2 with at least one split cut **76**(**1**) to collectively expose the end portions **46**(**1**), **46**(**2**) of the fiber sub-units **42**(**1**), **42**(**2**), respectively, from the cable jacket **40**. The distance L_2 may be, for example, 1.5 inches to provide sufficient access to the components inside the fiber optic cable **34** to form the fiber optic cable furcation assembly **32**(**1**). Exposing the end portions **46**(**1**), **46**(**2**) enables further processing steps to be applied to the fiber sub-units **42**(**1**), **42**(**2**) to prepare the fiber optic cable **34** for furcation.

It is noted that the cable jacket **40** may be cylindrically shaped and made of a strong material to protect contents of the fiber optic cable **34**. The strong material may comprise, for example, ultra-violet (UV) curable acrylate. The cable jacket **40** may also be flexible to better permit the fiber optic cable **34** to bend and thereby be pulled through conduits during installation.

FIG. **5**B is a side longitudinal view of the partially assembled fiber optic cable furcation assembly **32**(**1**) illustrating exposing the end portions **48**(**1**), **48**(**2**) of the optical fibers **36**(**1**), **36**(**2**) from the end portions **46**(**1**), **46**(**2**) of the fiber sub-units **42**(**1**), **42**(**2**) (Block **72**B of FIG. **4**). The exposing the end portions **48**(**1**), **48**(**2**) may include stripping the fiber sub-unit jackets **44**(**1**), **44**(**2**) from the optical fibers **36**(**1**), **36**(**2**) using at least one stripping tool, for example, a sheath knife. Once exposed, the optical fibers **36**(**1**), **36**(**2**) may be cleaned with a clean cloth (not shown) that may be dampened with isopropyl alcohol to remove loose debris. In this manner, the optical fibers **36**(**1**), **36**(**2**) may be prepared for securing to the fiber sub-unit jackets **44**(**1**), **44**(**2**) with the shrink tubes **52**(**1**), **52**(**2**). It is noted that the cable jacket **40** is shown with the split cuts **76**(**1**), **76**(**2**) opposite to each other and orientated longitudinally to gain better access to the fiber sub-units **42**(**1**), **42**(**2**).

It is noted that the fiber sub-unit jackets **44**(**1**), **44**(**2**) are cylindrically-shaped to allow the optical fibers **36**(**1**), **36**(**2**) to be disposed therein for protection. The fiber sub-unit jackets **44**(**1**), **44**(**2**) may comprise a strong, rigid material, for example, polypropylene to provide protection for the optical fibers **36**(**1**), **36**(**2**) against cable strain and bending. The fiber sub-unit jackets **44**(**1**), **44**(**2**) may each contain one or more of the optical fibers **36**(**1**), **36**(**2**) and may also contain strong material therein, for example, aramid fiber to direct tension applied to the fiber sub-unit away from the optical fibers **36**(**1**), **36**(**2**).

FIGS. **5**C-**5**E depict the optical fibers **36**(**1**), **36**(**2**) being secured to the fiber sub-unit jackets **44**(**1**), **44**(**2**) with the shrink tubes **52**(**1**), **52**(**2**). In this manner, the optical fibers **36**(**1**), **36**(**2**) may be free of direct coupling to the strength member **38** which would otherwise subject to the optical fibers **36**(**1**), **36**(**2**) to the coupling members **54**(**1**), **54**(**2**) and associated micro-bubbles which may cause attenuation. In this regard, FIG. **5**C is a longitudinal side view of the partially assembled fiber optic cable furcation assembly **32**(**1**) of FIG. **5**B with the shrink tubes **52**(**1**), **52**(**2**) disposed around the fiber sub-unit jackets **44**(**1**), **44**(**2**) and the optical fibers **36**(**1**),

36(2) (Block 72C of FIG. 4). Once the shrink tubes 52(1), 52(2) disposed or positioned around the fiber sub-unit jackets 44(1), 44(2) and the optical fibers 36(1), 36(2) then the shrink tubes 52(1), 52(2) may be secured. In an exemplary embodiment, each of the shrink tubes 52(1), 52(2) may be one (1) inch long. Half of a length of the shrink tubes 52(1), 52(2) may be abut against the fiber sub-unit jackets 44(1), 44(2), respectively, and another half of the length may abut against the optical fibers 36(1), 36(2), respectively.

Before securing the shrink tubes 52(1), 52(2), the extra fiber length 56 ("EFL") may optionally be disposed within the fiber sub-unit jackets 44(1), 44(2) to protect the optical fibers 36(1), 36(2) from cable strain prior to securing the shrink tubes 52(1), 52(2) (Block 72D of FIG. 4). FIG. 5D is a side view of the partially assembled fiber optic cable furcation assembly of FIG. 5C wherein the EFL 56 of the optical fibers 36(1), 36(2) may be disposed within the fiber sub-unit jackets 44(1), 44(2). Specifically, the EFL 56 may be created by pushing a distance L_4 of the optical fibers 36(1), 36(2) with force F_1 into the fiber sub-unit jackets 44(1), 44(2). As a result, the EFL 56(1), 56(2), or alternatively called "portions of the optical fibers 36(1), 36(2)," are formed free from tension and located within the fiber sub-unit jackets 44(1), 44(2) and adjacent to the shrink tubes 52(1), 52(2). The distance L_4 may be, for example, a one-quarter (0.25) inches. The EFL 56 enables tension from the cable strain F_S (FIG. 2A) to be directed to the strength member 38 and thereby avoiding placing the tension on the optical fibers 36(1), 36(2) which may cause attenuation.

FIG. 5E is a longitudinal side view of the partially assembled fiber optic cable furcation assembly 32(1) of either FIG. 5C or 5D depicting the optical fibers 36(1), 36(2) being secured to the fiber sub-unit jackets 44(1), 44(2) (Block 72E of FIG. 4). The securing may be accomplished by exposing the shrink tubes 52(1), 52(2) to heat energy 78 from a heat source 80, for example, hot air from a hot air device. The shrink tubes 52(1), 52(2) may constrict in a process called "heat shrinking" to a smaller diameter as the heat energy 78 may be absorbed to thereby secure the shrink tubes 52(1), 52(2) to the fiber sub-unit jackets 44(1), 44(2) and the optical fibers 36(1), 36(2). The shrink tube 52(1), 52(2) may, for example, comprise polyolefin and an adhesive to more securely attach the shrink tube 52(1), 52(2) to the fiber sub-units 42(1), 42(2) and the optical fibers 36(1), 36(2). Now that the optical fibers 36(1), 36(2) are secured to the fiber sub-unit jackets 44(1), 44(2), direct coupling to the strength members 38 with the coupling members 54(1), 54(2) is unnecessary, because coupling to the strength members 38 may be accomplished through the shrink tubes 52(1), 52(2) or the fiber sub-unit jackets 44(1), 44(2).

As discussed above, the fan-out tubes 64(1), 64(2) protect the optical fibers 36(1), 36(2) as they extend from the cable jacket 40. FIGS. 5F and 5G are longitudinal side views of the partially assembled fiber optic cable furcation assembly 32(1) of FIG. 5E with the fan-out tubes 64(1), 64(2) being at least partially disposed around the end portions 48(1), 48(2) of the optical fibers 36(1), 36(2) and adjacent to the shrink tubes 52(1), 52(2) (Block 72F of FIG. 4). The adjacent proximity of the fan-out tubes 64(1), 64(2) to the shrink tubes 52(1), 52(2) may prevent direct coupling of the optical fibers 36(1), 36(2) to the strength member 38 by preventing the coupling members 54(1), 54(2) and the strength member 38 from contacting the optical fibers 36(1), 36(2).

Several blocks are to be completed before the coupling members 54(1), 54(2) may secure components of the fiber optic cable furcation assembly 32(1). FIG. 5H is a longitudinal side view of the partially assembled fiber optic cable furcation assembly 32(1) of FIG. 5G with the coupling members 54(1), 54(2) provided in FIG. 5G disposed adjacent to the shrink tubes 52(1), 52(2) (Block 72G of FIG. 4). The adjacent proximity of the coupling members 54(1), 54(2) to the shrink tubes 52(1), 52(2) enables the shrink tubes 52(1), 52(1) to be secured to the cable jacket 40 with the coupling members 54(1), 54(2). The coupling members 54(1), 54(2) may also be disposed adjacent to the fan-out tubes 64(1), 64(1) for secure the fan-out tubes 64(1), 64(1) to the cable jacket 40.

The coupling members 54(1), 54(2) may comprise a strong material capable of establishing reliable bonds with various disparate materials. Consistent with these characteristics, the coupling members 54(1), 54(2) may be comprised of a hot melt adhesive comprising thermoplastic in a form of at least one solid glue member that may be disposed about the fiber sub-units 42(1), 42(2). In an exemplary embodiment, the coupling members 54(1), 54(2), may be, for example, a ThermoGrip® HM7116 hot melt adhesive made by Bostik, Inc. of Wauwatosa, Wis.

FIG. 5I is a longitudinal side view of the partially assembled fiber optic cable furcation assembly 32(1) of FIG. 5H illustrating the cable jacket 40 being disposed around the coupling members 54(1), 54(2) and tape 82 being holding the cable jacket 40 in place (Block 72H of FIG. 4). Disposing the cable jacket 40 around the coupling members 54(1), 54(2) enables the coupling members 54(1), 54(2) to be secured to the shrink tubes 52(1), 52(2).

Additional strength and performance may be added to the fiber optic cable furcation assembly 32(1) with an application of the outer shrink tube 60. FIG. 5J is a longitudinal side view of the partially assembled fiber optic cable furcation assembly 32(1) of FIG. 5I illustrating the outer shrink tube 60 being disposed around the cable jacket 40 (Block 72I of FIG. 4). The outer shrink tube 60 may have different dimensions than the shrink tubes 52(1), 52(2) but otherwise may be similar and accordingly will not be discussed in further detail.

FIG. 5K is a longitudinal side view of the partially assembled fiber optic cable furcation assembly of FIG. 5J illustrating the outer shrink tube 60 being secured to the fan-out tubes 64(1), 64(2) and the cable jacket 40 with the application of heat energy 78 conveyed from a heat source 80 to the outer shrink tube 60 (Block 72J of FIG. 4). The heat energy 78 may cause the outer shrink tube 60 to tighten and thereby secure the outer shrink tube 60 to the fan-out tubes 64(1), 64(2) and the cable jacket 40. The outer shrink tube 60 may also comprise an adhesive to form a strong bond with the fan-out tubes 64(1), 64(2) and the cable jacket 40. As the outer shrink tube 60 tightens, air is forced out of the fiber optic cable furcation assembly 32(1) thereby reducing or eliminating micro-bubbles which can cause attenuation. Further, the fiber optic cable furcation assembly 32(1) is made smaller after the outer shrink tube 60 tightens and thereby is easier to pull through conduits during installation.

After the outer shrink tube 60 is secured, the coupling members 54(1), 54(2) may be enabled to provide strength to the fiber optic cable furcation assembly 32(1). FIG. 5L is a top perspective view of the partially assembled fiber optic cable furcation assembly 32(1) of FIG. 5K disposed in a heater 84 illustrating the coupling members 54(1), 54(2) securing the cable jacket 40 to the shrink tubes 52(1), 52(2), and the strength member 38 (Block 72K of FIG. 4). The heater 84 may expose the coupling members 54(1), 54(2) of the fiber optic cable furcation assembly 32(1), for example, to one-hundred fifty (150) degrees Celsius for three (3) minutes to melt the coupling members 54(1), 54(2). Once melted, gravity and capillary action may pull portions of the coupling members 54(1), 54(2) so that the coupling members 54(1),

54(2) may come into contact with the other components of the fiber optic cable furcation assembly 32(1). The coupling members 54(1), 54(2) may be a hot melt adhesive comprising thermoplastic that may be activated by the heat and form bonds during the heating and subsequent cooling to room temperature. In this manner, the shrink tubes 52(1), 52(2) (FIG. 5E) may be secured to the cable jacket 40. Once secured with the coupling members 54(1), 54(2), the fiber optic cable furcation assembly 32(1) may be installed in the fiber optic equipment 50 (FIG. 3) and the optical fibers 36(1), 36(2) terminated, for example, with the fiber optic connectors 86(1), 86(2).

FIG. 6 is a schematic diagram to summarize the exemplary relationships discussed above between the components of the fiber optic cable furcation assembly 32(1). For example, the schematic diagram depicts the fiber optic cable furcation assembly 32(1) secured to the portion 68 of the fiber optic equipment 50 to provide strain relief through the strength member 38. The coupling members 54(1), 54(2) are secured to the cable jacket 40, strength member 38, and the shrink tubes 52(1), 52(2). Because the strength member 38 is attached to the fiber optic equipment 50 to provide strain relief, the coupling members 54(1), 54(2) transfer the cable strain F_S to the strength member 38 from one or more of the cable jacket 40 and the fiber sub-unit jackets 44(1), 44(2). As the strength members 38 are directly coupled to relatively stretchable components, namely the cable jacket 40 and the fiber sub-unit jackets 44(1), 44(2), this enables cable strain to be carried by the strength members 38 and shared by the stretchable components. The cable strain carried by the strength members 38 may be less likely to be shared with the optical fibers 36(1), 36(2), because the optical fibers 36(1), 36(2) are not directly coupled to the strength members 38 and attenuation may be reduced.

FIG. 7 introduces another exemplary fiber optic cable furcation assembly 32(2) now that the fiber optic cable furcation assembly 32(1) and the exemplary process 70 for furcating the fiber optic cable 34 have been introduced. The fiber optic cable furcation assembly 32(2) comprises a fiber optic cable 34 and a furcation 33(2) including the shrink tubes 52(1), 52(2) and the coupling members 54(1), 54(2) (not shown). In this regard, FIG. 7 is a longitudinal side view of the fiber optic cable furcation assembly 32(2) including the optical fibers 36(1), 36(2) of the fiber sub-units 42(1), 42(2) of the fiber optic cable 34 secured to the fiber sub-unit jackets 44(1), 44(2) of the fiber sub-units 42(1), 42(2) with the shrink tubes 52(1), 52(2) of the fiber optic cable furcation assembly 32(2). The optical fibers 36(1), 36(2) are without direct coupling to the strength members 38, similar to the fiber optic cable furcation assembly 32(1) of FIG. 2A. However, the fiber optic cable furcation assembly 32(2) includes the fan-out tubes 64(1), 64(2) arranged using a wrapping technique to enable the fiber optic cable furcation assembly 32(2) to fit easier through small conduits.

In this regard, FIG. 8A is a longitudinal side view of the fiber optic cable furcation assembly 32(2) of FIG. 7 in a partially assembled state of formation to illustrate the optical fibers 36(1), 36(2) being at least partially disposed within the fan-out tubes 64(1), 64(2) (Block 74A of FIG. 4). The fan-out tubes 64(1), 64(2) protect the optical fibers 36(1), 36(2) between the fiber optic cable furcation assembly 32(2) and the fiber optic connectors 86(1), 86(2) (FIG. 7). The fan-out tube strength members 66(1), 66(2) of the fan-out tubes 64(1), 64(2), respectively, may face the coupling members 54(1), 54(2) for securing to the cable jacket 40 as discussed below. It is noted that the fan-out tubes 64(1), 64(2) corresponding to the optical fibers 36(1), 36(2) may have tape 82A(1), 82A(2) applied, respectively, to provide organization and corresponding assembly efficiency.

FIGS. 8B and 8C are side views of the fiber optic cable furcation assembly 32(2) of the fiber optic cable 34 depicting that the process 70 may include disposing the fan-out tubes 64(1) adjacent to a radial holding member 88 and adjacent to at least one second securing member 90 (Block 74B of FIG. 4). Specifically, the at least one fan-out tube 64(1) may be placed adjacent to the radial holding member 88 and the second securing member 90 as depicted in FIG. 8B. Moreover, FIG. 8C illustrates the fan-out tubes 64(1) may be wrapped around the radial holding member 88 and the second securing member 90 to provide closer proximity between the second securing member 90 and the fan-out tubes 64(1). As shown further in FIG. 8C, at least one additional piece of tape 82B may hold the at least one fan-out tube 64(1) in a wrapped position around the radial holding member 88 and the second securing member 90.

In this regard, the second securing member 90 may include a cylindrical shape and the radial holding member 88 may be disposed within the second securing member 90. The second securing member 90 may be, for example, a hot melt adhesive comprising thermoplastic configured to bond the fan-out tubes 64(1), 64(2) together with the radial holding member 88. The radial holding member 88 may include a cylindrical shape and may be made of a material compatible with forming a bond to the second securing member 90. In an exemplary embodiment, the second securing member 90 may be, for example, a ThermoGrip® HM7116 hot melt adhesive made by Bostik, Inc. of Wauwatosa, Wis.

FIGS. 8D and 8E are longitudinal side views of the partially assembled fiber optic cable furcation assembly 32(2) of FIG. 8C depicting the fan-out tubes 64(2) being wrapped around the fan-out tubes 64(1) and securing with tape 82C (Block 74C of FIG. 4). Wrapping the at least one fan-out tube 64(2) enables a relatively compact structure which may be more easily bonded together with the second securing member 90. The resulting relatively compact structure may also be more easily pulled through conduits during installation at facilities having the fiber optic equipment 50 (FIG. 3).

FIGS. 8F and 8G are longitudinal side views of the partially assembled fiber optic cable furcation assembly 32(2) of FIG. 8E illustrating the fan-out tubes 64(1), 64(2) being further disposed around the optical fibers 36(1), 36(2) with the force F_2 as the strength members 38 are pulled back to enable the coupling members 54(1), 54(2) to be precisely disposed around the shrink tubes 52(1), 52(2), respectively (Block 74D of FIG. 4).

FIG. 8H is a longitudinal side view of the partially assembled fiber optic cable furcation assembly 32(2) of FIG. 8G illustrating the fan-out tubes 64(1), 64(2) being disposed adjacent to the shrink tubes 52(1), 52(2) (Block 74E of FIG. 4). In order for the fan-out tubes 64(1), 64(2) to be adjacent to the shrink tubes 52(1), 52(2), the fan-out tubes 64(1), 64(2) are disposed further around the optical fibers 36(1), 36(2) so that, for example, a distance L_5 (FIG. 8G) is traversed to dispose the fan-out tube strength members 66(1), 66(2) in close proximity to the coupling members 54(1), 54(2). In this regard, the fan-out tube strength members 66(1), 66(2) may be secured to the cable jacket 40 with the coupling members 54(1), 54(2).

FIG. 8I-1 is a longitudinal side view of the partially assembled fiber optic cable furcation assembly 32(2) of FIG. 8H illustrating the outer shrink tube 60 being disposed over the fan-out tubes 64(1), 64(2), the strength members 38, and the cable jacket 40. Heat energy 78 from a heat source 80 is

applied to secure the outer shrink tube **60** to the fan-out tubes **64**(**1**), **64**(**2**) and the cable jacket **40**. In this regard, the outer shrink tube **60** provides protection to the fiber optic cable furcation assembly **32**(**2**) by sealing the fiber optic cable furcation assembly **32**(**2**) against changes in humidity or temperature which may cause attenuation. Further, the outer shrink tube **60** constricts around the fan-out tubes **64**(**1**), **64**(**2**) and the cable jacket **40** as the heat energy **78** is applied, which eliminates or reduces air pockets within the fiber optic cable furcation assembly **32**(**2**) which can result in air bubbles causing attenuation.

FIG. **8**I-**2** is a side view of another embodiment of a fiber optic cable furcation assembly **32**(**3**) illustrating the strength members **38** exiting from the split cut **76**(**1**) in the cable jacket **40** and the outer shrink tube **60** secured around the partially assembled fiber optic cable furcation of FIG. **8**H. In this manner, the strength members **38** may be secured outside the outer shrink tube **60** to complete the furcation and add flexibility to customize the fiber optic cable furcation assembly **32**(**3**) for specific installation challenges.

FIG. **8**J is a top perspective view of the partially assembled fiber optic cable furcation assembly of FIG. **8**I-**1** disposed in a heater **84** to illustrate the coupling members **54**(**1**), **54**(**2**) melting and thereby securing the cable jacket **40** to the shrink tubes **52**(**1**), **52**(**2**), the strength members **38**, and the fan-out tubes **64**(**1**), **64**(**2**) (Block **74**F of FIG. **4**). It is also noted that the second securing member **90** may also bond the radial holding member **88** with the fan-out tubes **64**(**1**), **64**(**2**). The heater **84** may heat the coupling members **54**(**1**), **54**(**2**) and the second securing member **90** of the fiber optic cable furcation assembly **32**(**2**), for example, to one-hundred fifty (150) degrees Celsius for three (3) minutes to melt the coupling members **54**(**1**), **54**(**2**). The coupling members **54**(**1**), **54**(**2**) and second securing member **90** may be hot melt adhesives comprising thermoplastic that may be activated by the heat and later form bonds during the heating and subsequent cooling to room temperature. In this manner, once the bonds are formed with the coupling members **54**(**1**), **54**(**2**) and the second securing member **90**, then the fiber optic cable furcation assembly **32**(**2**) as depicted in FIG. **8**K may be installed in the fiber optic equipment **50** (FIG. **3**) and the optical fibers **36**(**1**), **36**(**2**) terminated. The optical fibers **36**(**1**), **36**(**2**) may be terminated with the fiber optic connectors **86**(**1**), **86**(**2**) (FIG. **7**). In this manner, the fan-out tubes **64**(**1**), **64**(**2**) may protect the optical fibers **36**(**1**), **36**(**2**) exiting from the cable jacket **40** in a compact configuration.

To summarize interconnections of the fiber optic cable furcation assembly **32**(**2**), FIG. **9** is a schematic diagram of the fiber optic cable furcation assembly **32**(**2**) secured to the portion **68** of the fiber optic equipment **50** to provide strain relief through the strength member **38**. The schematic diagram depicted in FIG. **9** for the fiber optic cable furcation assembly **32**(**2**) may be similar to the schematic diagram depicted in FIG. **6** for the fiber optic cable furcation assembly **32**(**1**) and so only the differences will be discussed for clarity and conciseness. Consistent with this concise approach, FIG. **9** depicts that the fiber optic cable furcation assembly **32**(**2**) may include the coupling members **54**(**1**), **54**(**2**) bonded to the fan-out tube strength members **66**(**1**), **66**(**2**). In this manner, the fan-out tubes **64**(**1**), **64**(**2**) may be securely attached as part of the fiber optic cable furcation assembly **32**(**2**). The outer shrink tube **60** may secured to the cable jacket **40** and the fan-out tubes **64**(**1**), **64**(**2**) to provide additional strength to the fiber optic cable furcation assembly **32**(**2**) and seal the fiber optic cable furcation assembly **32**(**2**) against temperature or humidity. The second securing member **90** may bond the radial holding member **88** and the fan-out tubes **64**(**1**), **64**(**2**) together to provide strain relief to the fan-out tube strength member **66**(**1**), **66**(**2**). It is noted that the fiber optic cable furcation assembly **32**(**2**) may include the fan-out tube strength members **66**(**1**), **66**(**2**) which may be attached to the coupling members **54**(**1**), **54**(**2**) to further protect the optical fibers **36**(**1**), **36**(**2**) from strain as they exit the cable jacket **40**.

As used herein, it is intended that terms "fiber optic cables" and/or "optical fibers" include all types of single mode and multi-mode light waveguides, including one or more optical fibers that may be upcoated, colored, buffered, ribbonized and/or have other organizing or protective structures in a cable such as one or more tubes, strength members, jackets or the like. The optical fibers disclosed herein can be single mode or multi-mode optical fibers. Likewise, other types of suitable optical fibers include bend-insensitive optical fibers, or any other expedient of a medium for transmitting light signals. Non-limiting examples of bend-insensitive, or bend resistant, optical fibers are ClearCurve® Multimode or single-mode fibers commercially available from Corning Incorporated. Suitable fibers of these types are disclosed, for example, in U.S. Patent Application Publication Nos. 2008/0166094 and 2009/0169163, the disclosures of which are incorporated herein by reference in their entireties.

Many modifications and other variations of the embodiments set forth herein will come to mind to one skilled in the art to which the embodiments pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings.

Therefore, it is to be understood that the description and claims are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. It is intended that the embodiments cover the modifications and variations of the embodiments provided they come within the scope of the appended claims and their equivalents. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

I claim:

1. A method of furcating a fiber optic cable, comprising:

exposing an end portion of at least one fiber sub-unit and an end portion of at least one strength member from a cable jacket of a fiber optic cable;

exposing an end portion of at least one optical fiber from an end portion of at least one fiber sub-unit jacket of the at least one fiber sub-unit;

securing the end portion of the at least one optical fiber to the at least one fiber sub-unit jacket with at least one shrink tube; and

securing the at least one shrink tube securing the at least one optical fiber to the at least one fiber sub-unit jacket, and the at least one strength member to the cable jacket with at least one coupling member to furcate the fiber optic cable without direct coupling of the at least one strength member to the at least one optical fiber.

2. The method of claim **1**, wherein securing the at least one shrink tube comprises heat shrinking the at least one shrink tube to secure the end portion of the at least one optical fiber to the at least one fiber sub-unit jacket.

3. The method of claim **1**, further comprising disposing at least one fan-out tube at least partially around the end portion of the at least one optical fiber and adjacent to the at least one shrink tube.

4. The method of claim **3**, further comprising securing the at least one fan-out tube to the cable jacket with the at least one coupling member.

5. The method of claim 4, further comprising coupling at least one fan-out strength member of the at least one fan-out tube to the cable jacket with the at least one coupling member.

6. The method of claim 5, further comprising securing the at least one fan-out tube to an outer surface of the cable jacket with at least one outer shrink tube.

7. The method of claim 6, further comprising disposing the at least one fan-out tube adjacent to a radial holding member and adjacent to at least one second coupling member.

8. The method of claim 7, further comprising heating the at least one second coupling member to secure the at least one fan-out tube to the radial holding member.

9. The method of claim 4, further comprising abutting the at least one fan-out tube against the at least one shrink tube.

10. The method of claim 1, further comprising coupling at least one strength member of the fiber optic cable to an inner surface of the cable jacket with the at least one coupling member.

11. The method of claim 1, further comprising disposing an extra fiber length (EFL) portion of the at least one optical fiber within the at least one fiber sub-unit jacket.

12. The method of claim 11, comprising securing the at least one shrink tube to the at least one optical fiber and the at least one fiber sub-unit jacket to maintain the extra fiber length portion of the at least one optical fiber within the at least one fiber sub-unit jacket.

13. The method of claim 1, wherein the securing the at least one shrink tube to the cable jacket of the fiber optic cable comprises heating the at least one coupling member to bond with the at least one shrink tube and the cable jacket.

14. The method of claim 1, wherein the at least one coupling member is comprised of a hot melt adhesive.

15. The method of claim 1, wherein the exposing the end portion of the at least one fiber sub-unit and the end portion of the at least one strength member comprises stripping and splitting the cable jacket.

16. A fiber optic cable furcation assembly, comprising:

a fiber optic cable, comprising:

a cable jacket;

at least one strength member; and

an end portion of at least one fiber sub-unit, the end portion of the at least one fiber sub-unit comprising an end portion of at least one optical fiber extending from at least one fiber sub-unit jacket of the at least one fiber sub-unit; and

a furcation provided on an end portion of the fiber optic cable, the furcation comprising:

at least one shrink tube securing the end portion of the at least one optical fiber to the at least one fiber sub-unit jacket; and

at least one coupling member securing the at least one shrink tube securing the at least one optical fiber to the at least one fiber sub-unit jacket, and the at least one strength member to the cable jacket to establish the furcation of the fiber optic cable without direct coupling of the at least one strength member to the at least one optical fiber.

17. The fiber optic cable furcation assembly of claim 16, wherein the end portion of the at least one optical fiber is at least partially disposed within the cable jacket.

18. The fiber optic cable furcation assembly of claim 16, further comprising at least one fan-out tube at least partially disposed around the end portion of the at least one optical fiber and adjacent to the at least one shrink tube.

19. The fiber optic cable furcation assembly of claim 18, wherein the at least one coupling member secures the at least one fan-out tube to the cable jacket.

20. The fiber optic cable furcation assembly of claim 19, further comprising at least one fan-out strength member of the at least one fan-out tube secured to an inner surface of the cable jacket with the at least one coupling member.

21. The fiber optic cable furcation assembly of claim 20, further comprising at least one outer shrink tube securing the at least one fan-out tube to an outer surface of the cable jacket.

22. The fiber optic cable furcation assembly of claim 20, further comprising at least one second coupling member securing a radial holding member to the at least one fan-out tube.

23. The fiber optic cable furcation assembly of claim 20, wherein the at least one strength member is secured to the inner surface of the cable jacket with the at least one coupling member.

24. The fiber optic cable furcation assembly of claim 16, wherein the at least one optical fiber within the fiber sub-unit jacket and adjacent to the at least one shrink tube is free from tension.

25. The fiber optic cable furcation assembly of claim 16, wherein the at least one coupling member is comprised of a hot melt adhesive.

26. The fiber optic cable furcation assembly of claim 16, wherein the at least one optical fiber is free from abutment with the at least one coupling member.

27. A fiber optic cable furcation assembly, comprising:

a fiber optic cable, comprising:

a cable jacket;

at least one strength member; and

an end portion of at least one fiber sub-unit, the end portion of the at least one fiber sub-unit comprising an end portion of at least one optical fiber extending from at least one fiber sub-unit jacket of the at least one fiber sub-unit; and

a furcation provided on an end portion of the fiber optic cable, the furcation comprising:

at least one shrink tube securing the end portion of the at least one optical fiber to the at least one fiber sub-unit jacket;

at least one fan-out tube disposed at least partially around the at least one optical fiber and abutting against the at least one shrink tube;

at least one coupling member securing the at least one fan-out tube, the at least one shrink tube securing the at least one optical fiber to the at least one fiber sub-unit jacket, and the at least one strength member to the cable jacket to establish the furcation of the fiber optic cable without direct coupling of the at least one strength member to the at least one optical fiber,

wherein the at least one coupling member is comprised of a hot melt adhesive.

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